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ABBREVIATIONS. — D. = Discussion; I. = Illustrated.
Names of authors, etc., are printed in *italics*.

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OF

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ABOLITION OF GRADE CROSSINGS IN THE CITY OF NEW BEDFORD.

BY WILLIAM F. WILLIAMS, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read before the Society March 18, 1908.]

THE first step towards securing the abolition of grade crossings in New Bedford was taken in 1893 by the employment of Mr. John D. Fouquet, a civil engineer of New York City, to examine the situation and report his recommendations. He advised that the streets be carried over the railroad. In 1894 the mayor and aldermen petitioned the Superior Court for the appointment of a commission to examine and report upon the best method of abolishing practically all of the main line crossings. The commission was appointed that same year, and in 1903 they made a report which was later recommitted for further consideration, the final report being signed December 21, 1905, and confirmed by the court, October 9, 1906.

It would be impossible, within the limits of this article, to go into the details of this long-drawn-out controversy. I shall therefore only briefly touch on those matters that are essential to an intelligent statement of the scheme as now being carried out.

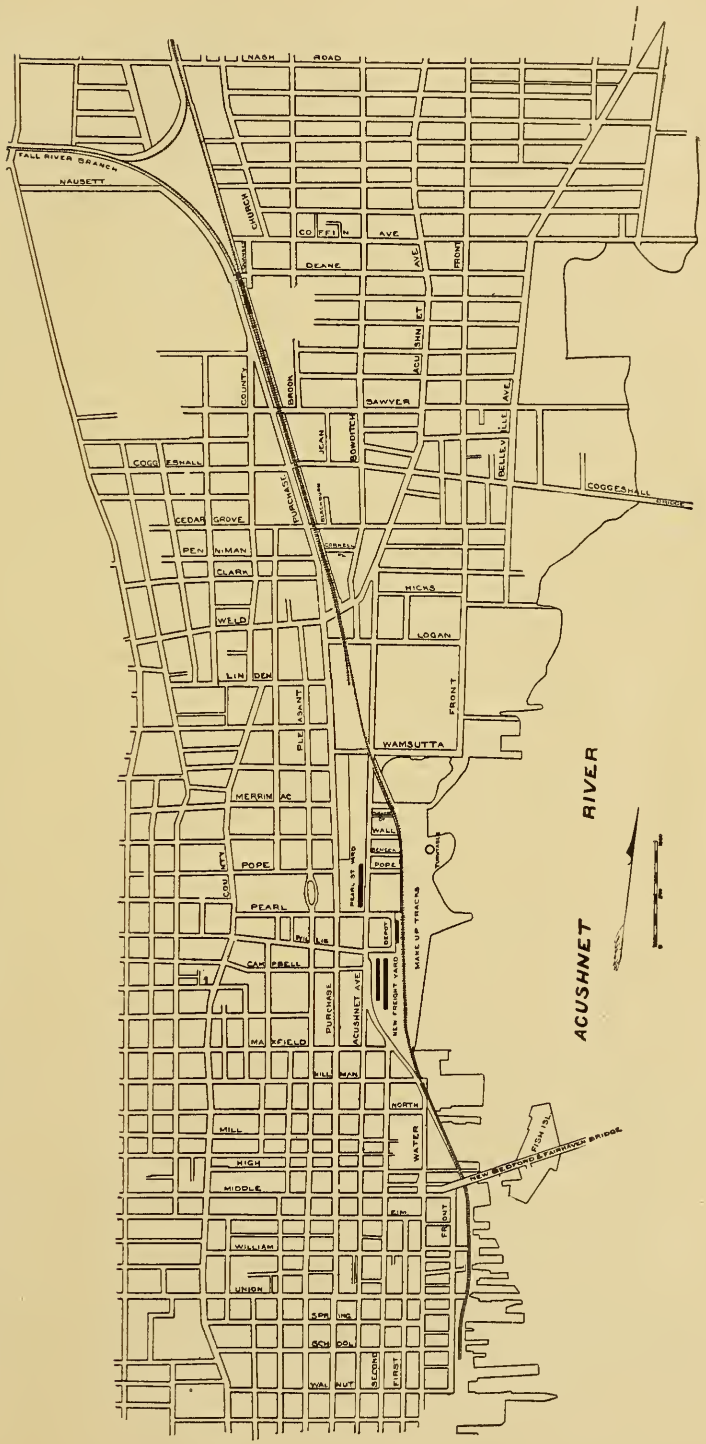
The petition of 1894 named the 16 crossings from Nash Road to the terminus of the line at the foot of School Street, a distance of about $2\frac{1}{3}$ miles. From the passenger station south for about 4 000 ft. the tracks adjoin the water front, and of the crossings named, 8 were in this section.

Of these water front crossings, that of the approach to the bridge to Fairhaven was the most important. In point of fact, it might be said to have been the inspiring cause of the petition. The legislature of 1893 had authorized the county commissioners to build a new bridge, and, if they saw fit, to petition for the abolition of the grade crossing at its approach. They decided, however, to widen the bridge at grade, and later commenced its construction on those lines. A public meeting was held about this time at which the proposed action of the commissioners was strongly denounced. Without doubt, public opinion, as far as shown by open expression of views, was in favor of eliminating the bridge crossing by carrying the approach to the bridge over the railroad. Yet it was evident that if an overhead bridge was built, the crossings south of this point could not be altered, inasmuch as there was not enough room between the railroad and the water to elevate the crossings. The construction of an overhead bridge would make it impossible to elevate the railroad, and the presence of tide water would prevent the railroad from being depressed.

In 1896 the bridge was widened and laid out at grade, with hardly a remonstrating voice, but when, in 1899, it was proposed to commence the construction of the New Bedford end of the bridge at grade, public opinion was again aroused in favor of an overhead structure. In 1900, after a long and very bitter controversy, an act was passed by the legislature which took the construction of the bridge out of the hands of the county commissioners and placed it in the city of New Bedford, with the approval of the railroad commissioners and the harbor and land commissioners. This led to the completion of the bridge as an overhead structure in 1902.

As soon as this act was passed, the city withdrew so much of its original petition as referred to the bridge crossing and those south of it. Therefore the final report of the Grade Crossing Commission dealt only with the crossings north of the bridge.

After several years, with many hearings and much discussion, it was decided by the Grade Crossing Commission that the general scheme of alteration should be to elevate the railroad about 14 ft. and depress the streets about 4 ft. The low rate of grade of the crossings and of the streets directly connected with the same made it impossible to carry the streets over the railroad without excessive grades, and within a reasonable limit of cost. The proximity of tide water, together with the underlying granite formation, precluded the depression of the railroad. It was also


NASH ROAD
FALL RIVER BRANCH
NAUSETT
CHURCH
COFFIN AVE
DEANE
AVE.
FRONT
ACUSHNET
COUNTY
BROOK
SAWYER
JEAN
BOWDITCH
BELLEVILLE AVE
COGGESHALL
COGGESHALL BRIDGE
PURCHASE ST.
CEDAR GROVE
PENNIMAN
CLARK
CORNELL PL.
HICKS
WELD
LOGAN
LINDEN
PLEASANT
FRONT
WAMSUTTA
ACUSHNET RIVER
MERRIMAC
WALL
POPE
PEARL ST YARD
PEARL
COUNTY
DEPOT
MAKE UP TRACKS
WILLIS
CAMPBELL
NEW FREIGHT YARD
PURCHASE
ACUSHNET AVE
MAXFIELD
HILLMAN
NORTH
MILL
WATER
HIGH
FISH ISL.
NEW BEDFORD & FAIRHAVEN BRIDGE
MIDDLE
ELM
FRONT
WILLIAM
UNION
SPRING
SCHOOL
WALNUT
SECOND
FIRST

decided that the Nash Road crossing was not used enough to justify its abolition. Therefore the change in grade of the railroad began at Nash Road and ended at the passenger depot.

May 30, 1903, the commissioners signed a report against which objections were filed in the Superior Court by the attorney-general and the attorney for the railroad on the grounds that in certain details it was contrary to law. The more important of these were that the commission had decided that Weld Street should be widened 30 ft., that a new street should be laid out adjoining the proposed new freight yard, and that Water Street crossing, which was not specifically named in the petition, should be abolished by relocating the railroad. Weld Street not only has the largest amount of traffic of any of the crossings, but its location is such that this traffic is bound to keep pace with the growth of the city. The street was 50 ft. in width and was occupied by one track of the street railway. Incidentally, I will state that our petition was brought before the passage of the law making street railways a party to the cost in grade-crossing proceedings. It was, therefore, impossible to place any part of the cost of abolishing this crossing upon the street railway, although it was apparent that it was to be very largely benefited by the widening and abolition. It will now have a double track and continuous operation, where formerly it had a single track with many interruptions. By the consent of all concerned, the report was referred back to the commission.

Shortly after this action, the attorney employed by the city died, and a little later Mr. Horatio G. Herrick, one of the commissioners, died. After these vacancies were filled, the questions in dispute were again taken up, and it was finally agreed at a conference with President Mellen that the city should lay out a widening of Weld Street at its own cost, and then no objection would be made to the commission providing for the abolition at its new width. The land required for the widening belonged to the Old Colony Railroad and the Union Street Railway Company, and both corporations gave the same without charge. The difficulty over Water Street was cured by a petition for that one crossing, which was referred to the same commission.

It was also agreed that the street adjoining the freight yard should be taken out of the report and built at the joint expense of the city and railroad; also that the bridges should be supported on steel columns set in the sidewalks near the curb line, and that they should have an open steel floor system with ties covered with 2-in. plank. The report of 1903 called for solid

floor bridges, and limited the use of columns in the sidewalks to the bridges over Weld Street and Acushnet Avenue.

One question in dispute was left for the commission to determine, and that was, Should the city or the railroad do the work in the streets? The commission decided that the railroad should do the excavation and the city all the rest of the work in the streets.

It is worthy of comment that this is probably the first general grade crossing alteration of any magnitude in this state in which the considerations of necessity and cost were so literally enforced in the plans and report finally adopted by the commission. This was in part due to the disinclination of the railroad to make any changes in the crossings, and in part to the insistence of the attorney-general that the cost must be kept down to the lowest figure compatible with standard railroad practice and a fair substitution for what both the city and the railroad then enjoyed. As a result, the general design is extremely plain, inartistic, and in some respects inadequate. On the other hand, the character of the work is substantial and durable, but the graceful arch of stone, concrete or steel is conspicuous by its absence.

The plan is inadequate in respect to the trackage provided for handling freight. No doubt it is equal to that already in use, but the freight facilities had been wofully insufficient for years. It may seem strange, but it was the representatives of the city who, realizing this situation, endeavored to have it rectified in the plans for the new yard. This was combated both by the state and the railroad, although the work on the alterations had only fairly begun when the railroad officials finally realized that more room was needed and plans were then made for continuing the use of the old Pearl Street yard for certain classes of inward freight.

New Bedford is 57 miles by railroad measure from the South Station, Boston, and is the terminus of the Taunton division of the Old Colony Railroad. It is also the terminus, through the medium of a ferry, of the Fairhaven branch of the same railroad, also of the direct line to Fall River, known as the Wattuppa Branch, a part of the Old Colony System, but all now leased by the New York, New Haven & Hartford Railroad.

The New Bedford & Taunton Railroad was completed to New Bedford in 1840, when the population was 13 000. It is now 90 000. It was a single-track road with four trains a day, two inward and two outward, terminating at Pearl Street in a depot

of very ancient design, the location of which was the subject of a long controversy, one faction favoring a location farther north; but it was decided by vote of the stockholders to locate it at Pearl Street.

In 1873 the railroad was extended along the water front to School Street, about 4 200 ft. south of Pearl Street. The extension diverged from the main line near Logan Street, about 2 500 ft. north of Pearl Street.

In 1886 a new passenger station was built on the extension just south of Pearl Street, and about 400 ft. east of the old station. The old station was soon demolished and freight houses built in its place. Strange to say, the public apparently took no interest in the location of the new depot, and a very attractive building was most poorly located for the convenience of the great majority of the patrons of the railroad. The station should have been built on the water front between Union Street and School Street, where connection was then and is now made with the Nantucket and Vineyard boats, the Cape Line via the ferry, and in the summer with the New York passenger boat.

The railroad enters New Bedford a short distance south of Braley's Station and is double tracked to its terminus, a distance of 7.4 miles. The grade crossing changes, however, are all included within a distance of about 11 000 ft. from Nash Road south. The direction of the railroad is slightly diagonal to the principal north and south streets, although one important thoroughfare, Purchase Street, adjoins it on the west from Weld Street, northerly about 3 200 feet. The most important crossings are Weld Street and Acushnet Avenue.

The cotton mills are nearly all on the water front and about evenly divided north and south of the freight yard. Only one mill in the city has direct rail connection. All receipts and shipments for the other mills are handled by teams.

The crossings abolished by the decree, in their order from the north, are:

Deane Street, 50 feet wide.

Sawyer Street, 50 feet wide.

Weld Street, 80 feet wide.

Logan Street, 50 feet wide.

Wamsutta Street, 45 feet wide, and Acushnet Avenue, 50 feet wide, a combined crossing, and

Water Street, 40 feet wide.

Wall Street crossing is abandoned and Coggeshall Street and Cedar Grove Street are carried under the railroad at the city's ex-

pense, as they were not laid out across the railroad location at the time of the petition.

The change in grade of the railroad begins on the south side of Nash Road, at which point it is about 66 ft. above tide water. It then runs level to Deane Street, where a head-room of 14 ft. is secured to the highway. This crossing is in substitution for the old crossing about 50 ft. further south, known as Purchase Street. From this point the grade follows practically parallel to the old grade at the rate of 0.765 ft. per 100 ft. to Weld Street; it then increases to 1.035 per 100 to Wamsutta Street and then to 1.12 per 100 to elevation 5.3 ft. at the north end of the depot, which is about 1 ft. above the old track level, requiring some readjustment of the station platform, but no change in the building itself.

The Water Street portion of the double crossing at Water and Hillman streets, south of the depot, is abolished by moving the tracks east and taking the old track location for the street. Formerly Water Street crossed the tracks and ended at Hillman Street. Public travel will be removed from this crossing, but travel to the two wharf properties immediately east will continue to cross the tracks at grade.

The elevated tracks are carried on solid fill within retaining walls and abutments of Portland cement concrete, except for short distances where it was possible either to slope within the company's lines or to secure land for the same at less than the cost of a wall.

A single track was first laid on the extreme west side of the railroad location from a short distance north of Deane Street to Weld Street, and all traffic was conducted on this single iron. The east wall and the east half of the abutments for the bridges north of Wamsutta Street were then built.

The material for the fill was brought by train from a gravel bank near Howland's Station, about ten miles north of the site of the work. Here it was loaded into Porter cars by steam shovel and unloaded by a steam plow, which worked rapidly and left the shovelers fresh to promptly clear the gravel away from the train and get the track up to its new grade for the next train. There will be approximately 300 000 cu. yds. of filling placed in the execution of this work.

In the building of the walls and abutments no very serious difficulties were met and good bottom was found without the necessity of using piles. Some very vexing conditions, however, were encountered, as, for instance, wherever the existing surface was above the original surface, as was the case for the most of the

distance south of Sawyer Street. It seemed as though some one with malicious premeditation had completely filled the site of the various foundations with bowlders of all sizes and shapes. Of course these had to be all taken out, because they were not properly laid and there was no knowledge as to the condition of the material under them.

The forms for the retaining walls were built with uprights of 4 in. by 6 in. timbers, the battened sections of the form being secured to these uprights with straps of thin hoop iron. Wedges were then driven between the battens of the form and the uprights to secure a solid connection without using spikes; any slacking of the form could also be easily taken up. The front and back forms were also tied together at intervals with pieces of hoop iron, which later were broken off and left in the concrete. The whole form was well braced from the outside by diagonal struts. The forms were built of boards planed on the inside face and thoroughly cleaned of cement and coated with crude oil before using.

The concrete for all the walls and abutments, except bridge seats and coping, was a 1 : 3 : 5 mixture, made very wet in rotary mixers. The concrete was discharged from the mixer into rectangular bottom dumping buckets, handled by derricks, and dumped where required in the forms with very little placing by hand.

Copings, bridge seats, parapets and pier foundations were made of a 1 : 2 : 4 mixture. Gravel was used almost entirely in all the concrete, and a very liberal latitude was allowed in the variations in size of same. Blocks of granite of all sizes and shapes were bedded in the foundations and upper part of the walls and abutments. The Dragon brand of Portland cement was used throughout this work.

The forms were removed as soon as the concrete had set enough to maintain its shape, generally inside of three days. The face of the concrete was then rubbed by hand with corundum blocks, the surface being kept wet during the operation. Holes of any size were filled with neat cement. The result of this treatment is a smooth surface with all grain marks of the boards and small defects in forms removed. Just how this smooth, blank surface will stand the test of time remains for the future to show.

Expansion joints are made about 60 ft. apart in the walls and one in the middle of the abutments. The west wall north of Weld Street is 7 ft. 2½ in. from the surface of the ground to the

Forms for Weld Street Abutment.

Forms for Concrete Wall on Purchase Street.

under side of the coping, which is 12 in. thick and 2 ft. 6 in. wide, with 3 in. projection. The wall is 6 ft. thick at the base and 2 ft. 6 in. under the coping. The foundation is 6 ft. 3 in. thick and about 4 ft. deep. The projection is on the front. The back of the wall is on a batter, and the face is plumb. The east wall and west wall south of Weld Street is about 15 ft. from surface of ground to under side of coping, the base 9 to 10 ft. in width.

The abutments are 10 ft. 6 in. through the foundations, stepping in one foot on the face at the surface, and are 4 ft. 3 in. thick under the bridge seat, which is 2 ft. 6 in. wide, 18 in. thick, with a 3 in. projection. The face of the abutment is vertical and the back on a batter.

As fast as the east halves of the abutments were completed, single-track timber trestles were erected across the streets and the filling put in place. A single-track timber trestle was also erected from Weld Street to Logan Street, a distance of about 240 ft., as the width of location did not admit of filling one side while operating on the other side.

In order to reduce the stoppage of street-car travel at Weld Street to as short a time as possible the trestle across this street was left out until the fill south of Logan Street and Wamsutta Street was mostly placed by backing the trains up from the south. As soon as the trestle was completed the balance of the fill was placed and then the passenger trains commenced running overhead.

At this time the widened portion of Weld Street had been graded and paved, and the north track of the street railway laid, as far as the single track at grade, which was then being used by freight trains. Team and foot travel was not interrupted at any time on this crossing. Street car travel was stopped November 26; and on Sunday, December 22, freight trains were also run overhead, the single track at grade removed, and at 6 o'clock in the evening the street cars were running under the trestle on the permanent north track.

In every way the Wamsutta and Acushnet Avenue crossing has been the most difficult to construct. Acushnet Avenue, running north and south, crosses Wamsutta Street at about a right angle. Wamsutta Street is 45 ft. wide and Acushnet Avenue is 50 ft. wide. The railroad, however, crosses both streets at a long skew, making an angle of about 28 degrees with Acushnet Avenue. This made it very difficult to arrange the bents of the trestle so that teams could pass through on both streets.

The tracks also cross Wamsutta Street to enter the Pearl

Street freight yard. The decree abolished these tracks, but it has been found necessary to continue the use of the yard, and a single-track overhead bridge will provide an entrance to it. This freight yard is still being operated and has never been closed during the construction.

The grades of both Acushnet Avenue and Wamsutta Street are lowered about 5 ft. and the clear head-room will be $13\frac{1}{2}$ ft. The presence of tide water and a very important sewer made it impossible to lower these grades any more.

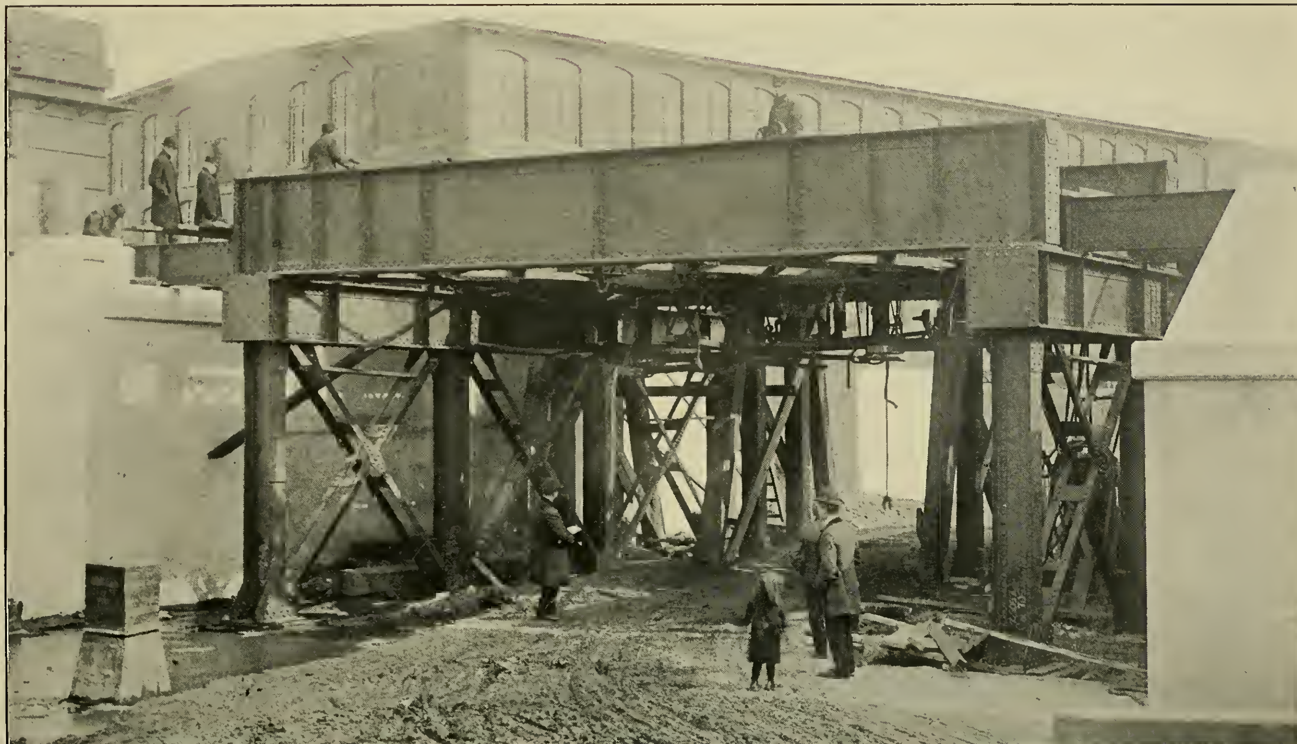
The railroad embankment south of Wamsutta Street has natural slopes on both sides, and a natural slope next to the avenue north of this street.

The grade of Wamsutta Street to the west will be 7.5%, but only 1% east of the avenue. The grade of Acushnet Avenue is worked out with 1.2% rate to the north and a 1% rate to the south. It was of the greatest importance to keep the rates on the avenue low on account of the heavy loads hauled and the low rate of grades on this street from the freight depot north.

To provide all the room possible for teams, and because the railroad abuts on the west side of the avenue from Logan Street to Pearl Street, a 9-ft. sidewalk will be built on the east side of the avenue only, and on the north side of Wamsutta Street, east of the avenue. West of the avenue there will be two sidewalks. The sidewalks will have granite curbs and a coal-tar concrete surface. The roadways will be paved with granite blocks laid on a 5-in. Portland cement concrete foundation. A portion of the paving is already laid; in fact it was necessary to do this work as soon as the grading was completed. It was utterly impossible to maintain travel over the graded surface and it was out of the question to cut off the use of the street.

The presence of the track at grade for serving the Pearl Street freight yard, complicated our work in the avenue, so that at one time it was necessary to divert travel through a portion of the freight yard and an old car house. One half of the street was then cut to grade and paved.

The most difficult piece of work in connection with the street changes was the construction of a concrete sewer to take the place of two brick sewers, one of 24 in. diameter in the middle of Acushnet Avenue from Wamsutta Street south, the other of 42 in. diameter, diverging from the sewer in the middle of the avenue north of the crossing and then following the gutter line south. This location conflicted with the foundations of the piers, so both sewers were combined in one in the middle of the



Deane Street Bridge,

street. The grade of the invert of the sewer was fixed by that of the sewers to be connected by the new sewer. This, with the cut in grade at the intersection of the streets, made it necessary to adopt a rectangular section 3 ft. by 7 ft., for a length of 110 ft. This was gradually changed at both ends to a horseshoe section, i. e., a semi-circular arch of 6 ft. diameter on vertical sides, 1 ft. high and a nearly flat bottom. The top of the rectangular section was made 12 in. thick with 8-in. 18-lb. I-beams imbedded therein, spaced 2 ft. 3 in. on centers and tied together with ¾ in. rods. The portions connecting the rectangular with the horseshoe section are reinforced with ½-in. round rods, spaced from 6 in. to 9 in. on centers and wired to three ¾-in. longitudinal rods, spaced about 2 ft. on centers. The block paving is laid directly on top of the reinforced portions of the sewer. The proportions of the concrete for this work were 1 : 2 : 4 and 1 : 3 : 5, using Dragon Portland cement. The stone was crushed granite, varying from screenings to stone 1½ in. in diameter. Collapsible wood forms, in 12-ft. lengths, were used and all the work was done by day labor. The old sewer was built on top of marsh mud varying in thickness from 1 ft. to 4 ft., all of which had to be taken out and the space filled with concrete rubble. The invert was built first, about 48 hours ahead of placing the form for the sides and arch. The forms were only allowed to stand over night, but we had no trouble from sagging or distortion. The concrete was mixed quite wet and thoroughly spaded next to the forms, so that we got a very smooth surface on the inside.

The work was performed under more than the usual difficulties, owing to the large amount of teaming that had to be maintained, poor banks requiring sheeting the whole distance, the presence in the trench for its entire length of a 12-in. gas main, and part of the way of an 8-in. main also.

The railroad is to be carried over Deane, Sawyer, Coggeshall, Cedar Grove, Weld and Logan streets by steel plate girder bridges, carrying three tracks, and over Wamsutta Street and Acushnet Avenue by the same type of bridge carrying four tracks. The girders of these bridges are carried upon steel columns set in the sidewalk just inside the curb line and not upon the abutments, with the exception of the bridge over Acushnet Avenue. Only the track stringers rest upon the abutments. The columns are set on concrete piers, whose foundations are 7 ft. square for all except the Acushnet Avenue bridge, where they are 8 ft. square. The tops of the piers are at the grade of the sidewalk. As already stated, these bridges have open floor systems, but the

ties are to be covered with 2 in. plank to prevent ashes, oil, etc., from dropping on the street below. As an additional protection to pedestrians, a canopy is to be built over the sidewalks the full length of the bridge.

The bridges represent a new departure in design and one that can hardly be commended as pleasing to the eye. The city, however, had no voice in the selection of the design as the decree says they " shall be proportioned and constructed in accordance with the General Specifications for Railroad Bridges of the New York, New Haven & Hartford Railroad Company."

By the terms of the decree the freight tracks at grade across Wamsutta Street are to be discontinued. This was supposed to do away with the Pearl Street yard and freight houses; so it was ordered that the small yard south of the passenger depot be enlarged and regraded, also that there should be built an outward freight house of brick, 360 ft. long by 30 ft. wide, and an inward freight house of brick, 360 ft. long by 50 ft. wide, together with platforms, tracks and driveways paved with granite blocks. The office building is on the end of the inward house. On the car side, these houses are practically a continuous line of sliding doors, so that there will be no difficulty about having the car doors opposite a door in the building.

The street built by the city and railroad as a continuation of Water Street on the west side of the freight yard has a driveway that is 32 ft. wide, paved with granite blocks on a concrete base. There is an 8-ft. sidewalk on the west side. The railroad driveway adjoining it on the east is about 45 ft. wide, thus making a continuous paved surface nearly 80 ft. wide, a fine and much needed improvement for the teamsters.

The car entrance to this yard is at Hillman Street; but trains must pull down across Hillman Street to the New Bedford and Fairhaven bridge and then be backed up into the yard to unload or load, to again be pulled out and backed up into the make-up and storage yard east of the main line and north of Maxfield Street. This latter yard was made by filling a portion of the water front.

The total area of the new freight yard, including driveways, is 239 000 sq. ft. The available length of trackage is 2 880 linear feet for houses and platforms and 2 385 linear feet for bulk freight.

The area of the make-up and storage yard is 447 000 sq. ft. and the total length of trackage, including ladder tracks, as laid out by the plans of the decree, is about 24 000 ft. Considerable

additions, however, have been made to this yard by the company on its own account. They have also abandoned the old round-house, turntable and coaling station south of Logan Street and built a new 6-stall round-house at the northeast corner of the new storage yard, also a new turntable, with concrete walls and bottom, capable of handling the heaviest engines on the line. This table never should settle, as it is built on a ledge of granite which formerly outcropped about 20 ft. above the present level of the tracks.

A short distance south of the turnable is the coal pocket and ash pit. The coal pocket has a capacity of 100 tons and is filled by a bucket elevator operated by an electric motor which takes the coal from a pit below the track where it is dumped from cars on a trestle to the east of the pocket. The ash pit is built of concrete with the standard fittings of this company. As this is made ground, the foundations for pocket and pit had to be built on piles.

Still further south is a new 50 000 gallon water tank, also built on a concrete and pile foundation. At present this tank is kept filled with city water, but later it is the intention of the company to relay its pipe from wells near the track south of the Acushnet Station.

Deane Street, Purchase Street and Sawyer Street, within the limits of changes in grade of same, have been macadamized. Weld Street, Acushnet Avenue and Wamsutta Street are paved with granite blocks on a concrete base. Logan Street is paved with granite blocks on a sand base.

The entire cost of eliminating these crossings was estimated in April, 1906, at $998 700. Of this amount, $823 700 was for railroad construction and engineering; $75 000 for street work, and $100 000 for land damages. This last item may be low, but the construction will come within the estimate. The railroad, however, has already spent a considerable sum and will spend more, outside the decree requirements, securing necessary additional facilities.

The engineer in general charge of this work is Mr. B. T. Wheeler. The engineer in charge on the work was Mr. J. W. Capron, to August, 1907, and since that time Mr. P. S. Perkins, all of the New York, New Haven & Hartford Railroad. The contractor is Mr. J. K. Ryan, of New York, whose representative on the work was Mr. J. F. Keon.

All work within the streets, outside of grading, has been done by the city under the general direction of the city engineer.

[Note. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by September 15, 1908, for publication in a subsequent number of the Journal.]

SOME CAUSES WHICH TEND TOWARD THE FRACTURE OF STEEL RAILS.

By James E. Howard, Civil Engineer.

[Read before the Boston Society of Civil Engineers, May 20, 1908.]

Steel rails, in service, are required to sustain direct loads of compression as well as bending stresses received from the wheels upon the running surfaces of the heads. Adequate strength may be provided for these stresses by suitable cross-section dimensions and disposition of the metal, in the same way they would be met in other engineering examples, but there are limitations to the intensity of the stresses which may be applied to the area of contact between the wheels and the rail. The latter part of the problem is peculiar to rails.

In reviewing the causes of fracture it is convenient to consider the subject under two headings: (1) Causes which depend upon or are chiefly influenced by the conditions of service, that is, those which the users of the rails are responsible for; (2) those traceable to the values of the physical properties, or the structural state of the steel in its relation to service requirements. The rail-makers have to do with the second group of conditions.

Under the first group of conditions, the effect of wheel pressures will be referred to. Fig. 1 shows the end view of a rail fractured in the testing machine. This represents a rail which had been in service and showed on the running surface of the head evidence of the flow of the metal caused by wheel pressures. In the fracture of this rail the initial point was at the inner edge of the running surface of the head, the center of radiation marking the place where rupture began.

The flow of the metal of the head, apparent to the eye, witnessed very generally in portions of the track, may be taken as evidence of exhausted ductility of the metal. The ability of the steel to elongate, as found in the primitive state of the rail before going into service, is lost by reason of its development, and the rail at first tough and capable of being bent is now brittle and will bend only to a limited extent before rupture.

The brittleness is due to the flow of the metal at and immediately below the running surface of the head. The structural continuity has not been destroyed, as may be shown upon anneal-

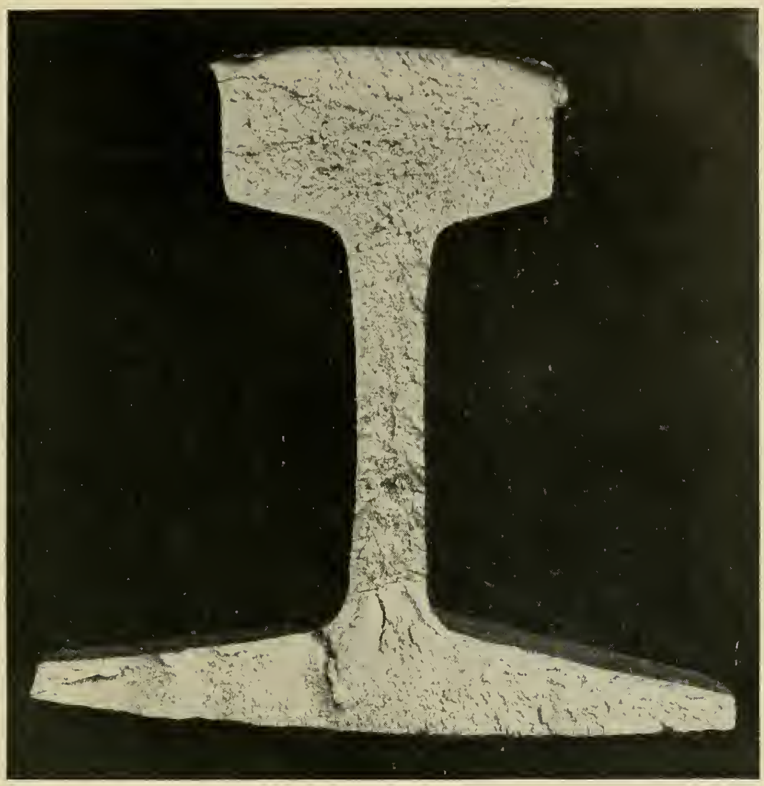


FIG. 1. End View of a Rail Fractured in the Testing Machine, showing Flow of Metal at Running Surface of Head due to Wheel Pressures.

FIG. 7. Difference in Bending Qualities shown by Rail after having been in service according to the Direction of Loading.

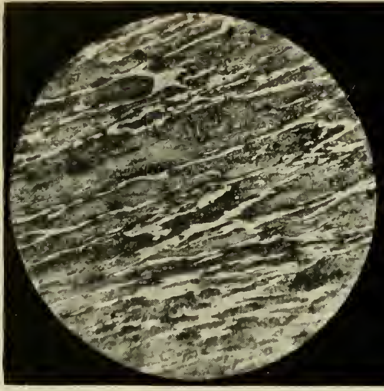


FIG. 3. Distorted Microstructure just below Running Surface of Head of Rail shown in Fig. 1.

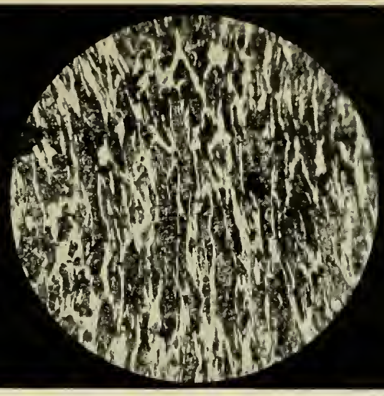


FIG. 4. Distorted Microstructure of Fin at Edge of Rail shown in Fig. 1.

FIG. 5. Microstructure at Junction of Distorted and Unaffected Metal of Rail shown in Fig. 1.

FIG. 2. Normal Microstructure of Metal in Head of Rail shown in Fig. 1.

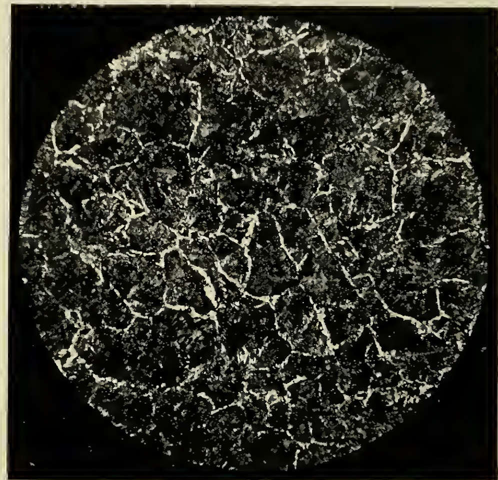


FIG. 6. General Microstructure of Head of Rail shown in Fig. 1, after Annealing. The same structure now pertains to the parts which had been affected by wheel pressures as to other portions of the head.

ing the metal, which effects a restoration in its ability to elongate. A rail from service will not bend well with the head on the tension side, since the surface metal has been subjected to cold flow in advance of its being worn away by abrasion.

Removing the surface metal, in the planer, restores the bending qualities of the rail, but in this case it is necessary to plane away the metal from the sides as well as from the top of the head, that is, as far down as the cold flow has taken place.

The distorted structure of the metal affected by cold flow is readily shown by means of the microscope. Figs. 2 to 6 inclusive are photomicrographs of different parts of the rail shown in Fig. 1, the magnification being about 84 and 110 diameters. Fig. 2 represents the normal structure of the metal in the head of the rail. Fig. 3 shows the distorted, flattened shape of the grains just below the running surface at the middle of the width of the head. The direction of flow was obliquely downward, which changed its course as the edge of the head was reached. At the edge, where a fin was formed, the longer axes of the grains are found in a position nearly vertical, as shown by Fig. 4.

The metal on the border between the affected and unaffected zones is shown by Fig. 5, the depth ranging from three to five hundredths of an inch below the running surface.

The sample from which these photomicrographs were taken was subsequently heated to a bright yellow color, which annealing heat effected a restoration in the grain of the steel, so far as uniformity of structure went. Fig. 6 shows the resulting microstructure, which resembles the normal structure in the primitive state, but somewhat finer in size.

The difference in the bending qualities of the same rail according to the head being on the tension or compression side is shown by Fig. 7. The upper piece of rail in the figure was bent with the head in compression, while the lower one of the cut had the head on the tension side of the bend.

Rails of this series of tests have ruptured with a deflection of only 3 to 5 degrees when the head was in tension, but remained unruptured when bent through an angle of 20 degrees or more with the base in tension. After annealing these old rails, of exhausted toughness, the bending qualities were restored, after which the rail could be bent in either direction through about the same number of degrees without fracture.

Fig. 8 is a side view of a rail broken in the testing machine, one in which lines of scale were detached from the surface of the web. The magnetic oxide is detached from the metal when

stresses reach or exceed the elastic limit of the steel. Places of overstrain in steel rails may be located by reason of the disturbance of the scale, and this takes place when rails are gagged in the process of cold straightening. While overstraining by gagging brings about a series of phenomena which tend toward final rupture, still it has not been the privilege of the speaker to examine any fractures in rails which seemed to owe their origin to this cause.

Fig. 9 represents another rail fracture made in the testing machine. The rail was tested with the base on the tension side. The cut is introduced to show the effect, in locating rupture, of a slight indentation made on the upper edge of the flange, the fracture of this sample having started at an indentation on the right flange of the base, the cut printing too deep to clearly show the place in this illustration.

It is desired to emphasize the fact that steel surfaces generally afford the means of judging where a line of fracture has its origin. In the case of granular fractures the center of radiation marks the starting point, the recognition of which is an aid toward ascertaining the cause which contributed toward rupture.

The slipping of the driving wheel of the locomotive when starting a train may cause roughness of the metal of the rail accompanied by intense heating of the immediate surface metal of the head. The appearance of the running surface of a rail head which has been subjected to this treatment is shown by Fig. 10. Necessarily tires and brake shoes are exposed to similar treatment, but rails only will now be referred to. In addition to the loss in ductility of the steel by reason of its flow under the wheel pressures, the metal at the running surface is hardened through this action of the wheel. Showers of sparks attend instances of this kind, from which the high temperature acquired by the particles of the steel may be judged of. There follows also a sudden reduction in temperature through conductivity of the cold metal below, which has an effect similar to quenching steel from high temperatures in water or other quenching liquids, and there results a surface hardening of the metal.

During this period of hardening the surface metal is placed in a state of intense tension, relief from which is experienced by the development of cracks in the steel. These cracks are a menace to the integrity of other parts of the rail, and may extend and result in complete fracture. Fig. 11 shows, at the darkened corners of the running surface, thermal cracks, which had begun to extend into the head, the result of this hardening proc-

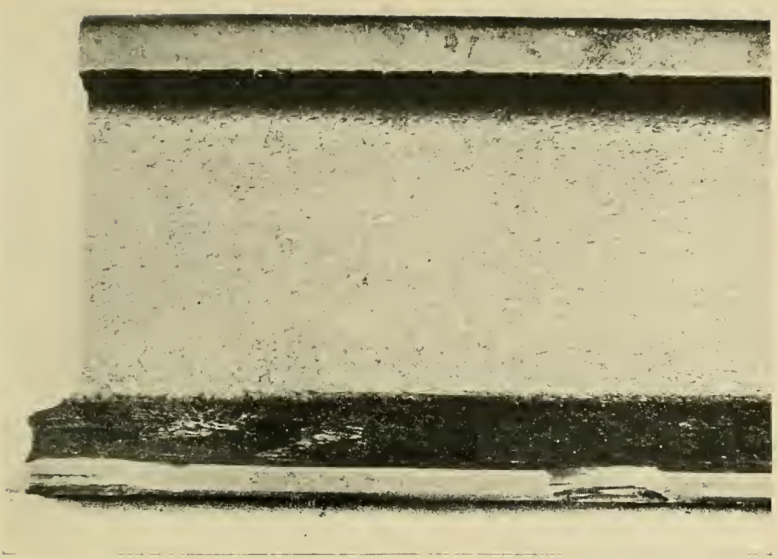


FIG. 8. Side View of Rail, Broken in the Testing Machine, showing how Scale was Detached from Surface of Web.

FIG. 9. End View of Rail Fractured in the Testing Machine. Rupture began at an indentation on upper edge of base, right-hand side.

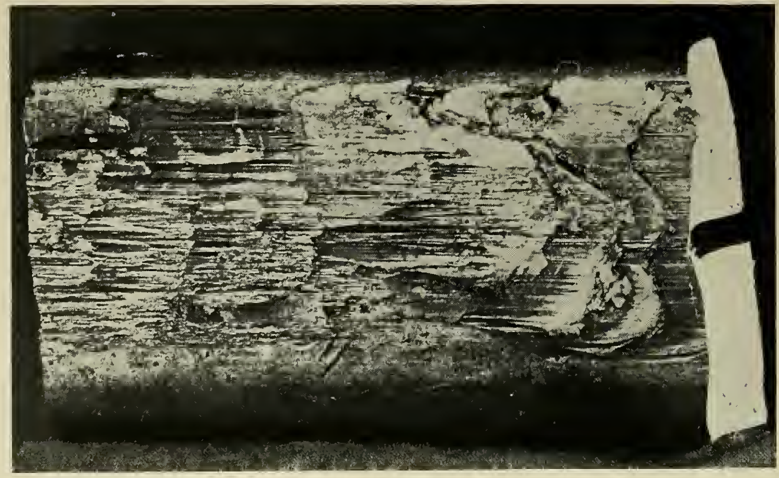


FIG. 10. Running Surface of Head of Rail, Roughened by Driving Wheels of Locomotive, Surface Hardened and Thermal Cracks Started.

FIG. 17. Markings on Cross Section of Rail, developed upon Polishing and Etching.

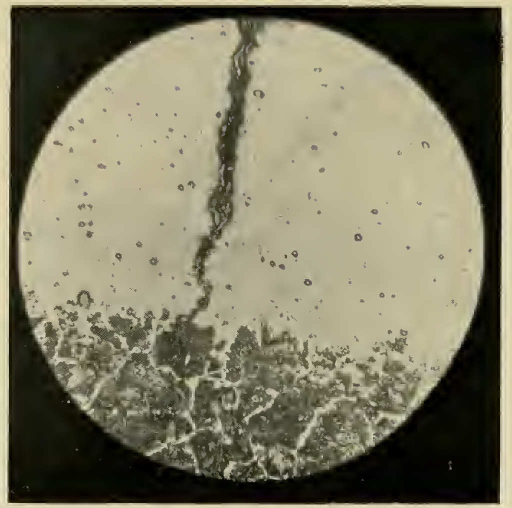


Fig. 15.

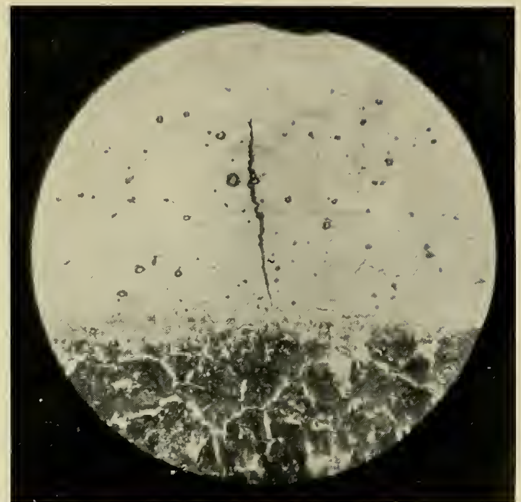


Fig. 16.

Thermal Cracks in Head of Rail shown in Fig. 10. Magnification 110 Diameters. Cross Section of Rail.

Fig. 11. Cracks Started in Head of Rail shown in Fig. 10, caused by Action of Wheels of Locomotive. Dark corners indicate the cracks which were developed.

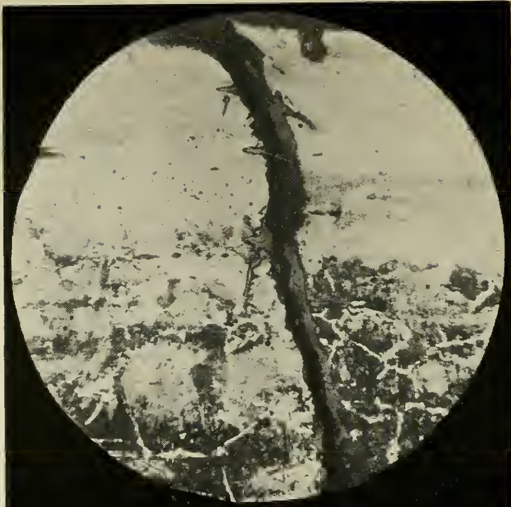


FIG. 12.
Upper
End.

FIG. 13.
Middle
Portion.

FIG. 14.
Lower
End.

Thermal Crack in Head of Rail shown in Fig. 10. Magnification 110 Diameters.
Longitudinal Section of Rail.

ess. Fractures thus begun may progressively extend deeper and deeper until there is a serious weakening of the rail.

A microscopic examination was made of the thermal cracks which had formed in the head of this rail and are illustrated in Figs. 12 to 16 inclusive. The first three of these figures show parts of the same crack, taken at different depths, successively, the magnification being 110 diameters. In Fig. 12 the hardened metal, immediately below the running surface, appears white in the cut, this portion not being acted upon by the etching bath, a 4 per cent. solution of picric acid. This crack is viewed on a longitudinal section of the rail head. The upper portion has a curved direction corresponding to the flow which the surface metal experienced before hardening took place. The central part of the depth of the crack is shown in Fig. 13, and the lower part in Fig. 14.

Figs. 15 and 16 show thermal cracks as found on a transverse section of the head of this rail. The cracks are formed in direction nearly normal to the running surface, the flow of the metal under the wheel pressures not causing a curved shape such as witnessed in the cracks which were viewed on the longitudinal section of the head. One of these two cracks is seen to have separated the hardened portion of the head and reached into the unhardened metal below, while the other crack is an interior one lying wholly within the zone of hardened metal.

With the presentation of these illustrations the causes of steel rail fractures resulting from service conditions will be left and metallurgical features under the second heading taken up.

When a rail is cut apart and its cross-section polished and etched, certain markings usually appear, the general character of which are similar to those shown by Fig. 17. They not infrequently appear to the eye before etching, a suitable machine-tool cut having been taken across the rail section.

A 10 per cent. solution of iodine was used in the etching of the sample represented in the present figure. These familiar markings indicate a lack of uniformity of some kind in the steel.

Markings, which appear as dots or lines on the cross-section of the rail, are found to be streaks, some of which are light colored and others dark colored, when a longitudinal section of the rail is examined.

Fig. 18 shows one pronounced streak which can be followed over the edge and seen on both the top and the end surfaces of the rail. Since the dots and lines on the cross-section are found at different places in the rail, their connection with longitudinal

streaks having been established, it follows that streaks will be found at different depths from the surfaces when the metal is examined by planing off the heads or bases in steps at different depths. Fig. 19 shows the head of a rail planed off at two steps, an inclined section connecting them.

Longitudinal lines on the bases are similar in appearance to those which are found in the heads. Fig. 20 shows the base of a modern rail of domestic manufacture, while Fig. 21 shows streaks in the base of an early English rail.

It may properly be inferred that streaked rails are not confined to those of recent manufacture, although it should not be assumed that all kinds of streaks are equally detrimental to the integrity of the rail.

With the view of determining some of the characteristics of the metal at the dark colored dots and lines, a thin cross section of a rail was planed off, as shown by Fig. 22. Upon bending the several parts of this thin section, which was first cut apart detaching the web from the head and base, it was found that the metal ruptured more readily along the line of a streak or at the dark dots than in other portions of the steel.

The effect of these streaks in causing brittleness is a matter upon which there can be no doubt, and since the so-called "moon-shaped" fractures in the bases of rails have their origins in longitudinal paths, the primary cause of such breaks is attributed to the presence in the steel of the longitudinal streaks just described.

Fig. 23 shows a fracture in the base of a rail, one which was formed in the testing machine, a typical "moon-shaped" or crescent break. This fracture was made along the line of a streak, and in continuation of one which occurred in the rail when in the track.

Extreme brittleness generally characterizes these breaks; the metal along the streak presents a striated appearance on the fractured surface, and preceding rupture there is hardly any display of permanent set in the metal. Photomicrographs, Figs. 24, 25 and 26, show the behavior at a streak when moderate bending stresses are applied, bringing the metal into tension in that part of the rail. The magnification of these figures is 150 diameters.

Fig. 24 shows the primitive state at a place on the base of a rail, the continuity of the material across this streak being unimpaired when first examined. Upon straining the sample containing this streak a fissure was developed, which may be seen in Fig. 25 as an irregular dark line within the borders of the streak.

Fig. 18. Markings on Cross Section of Rail, developed upon Polishing and Etching, showing Connection between End Markings and Longitudinal Streaks.

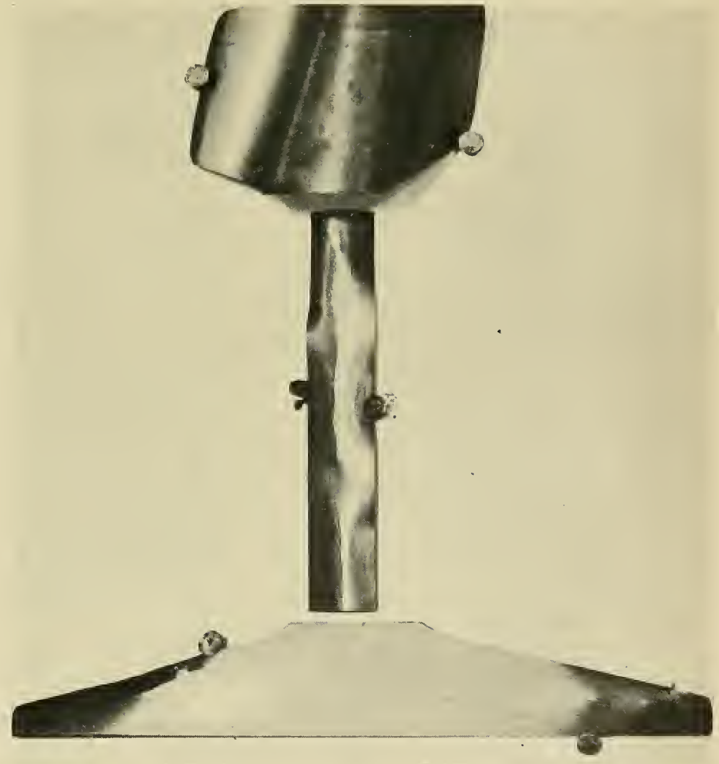


Fig. 22. Bending Tests made upon a Thin Section of Rail, showing Fractures on Line of Streaks or at Dark Colored Dots developed by Etching.

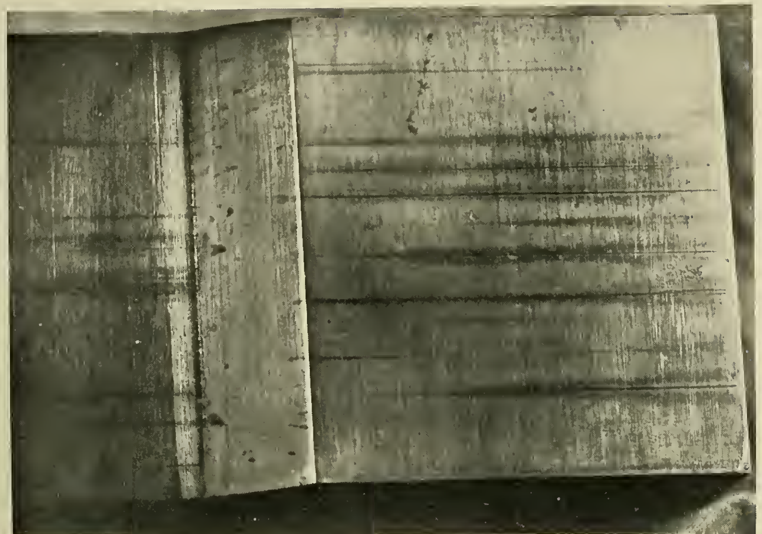


Fig. 19. Longitudinal Streaks on Head of Rail, at Different Depths.

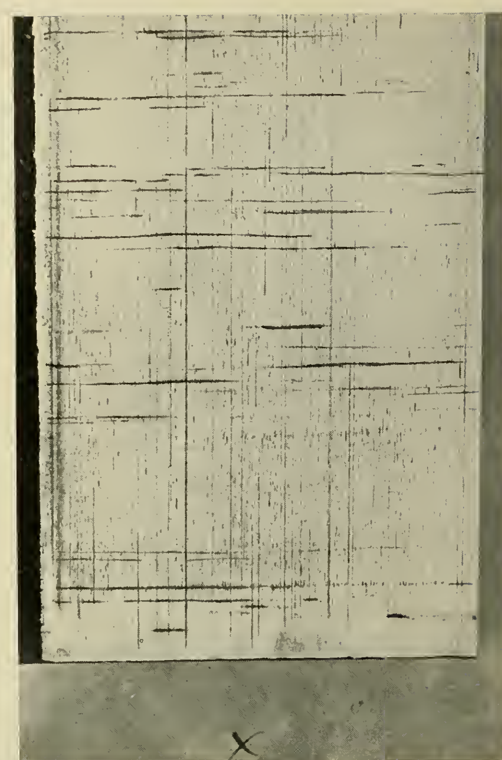


Fig. 20. Longitudinal Streaks on Base of Rail of Domestic Manufacture

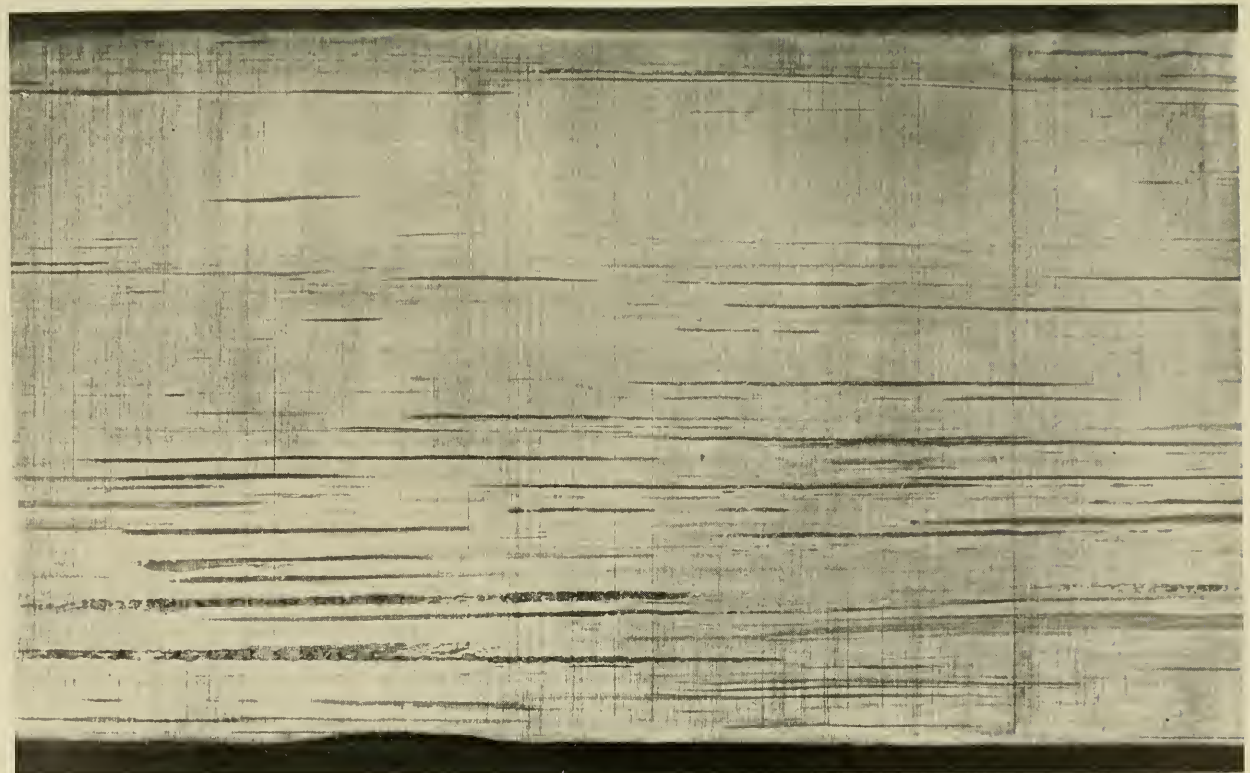


FIG. 21. Longitudinal Streaks on Base of Rail of Early English Manufacture.

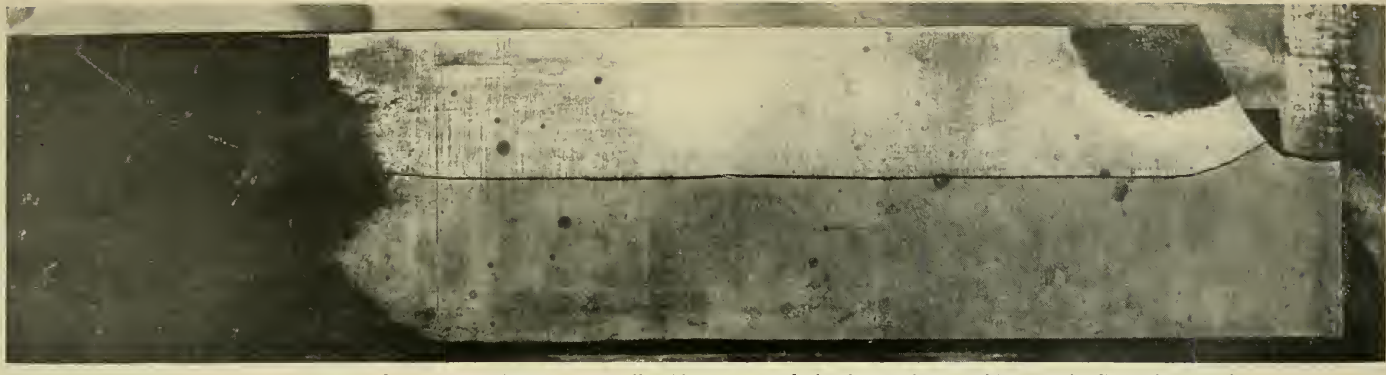


FIG. 23. "Moon-Shaped" Fracture in Base of Rail. Fracture made in the testing machine on the line of a streak, in continuation of one which occurred in the track.

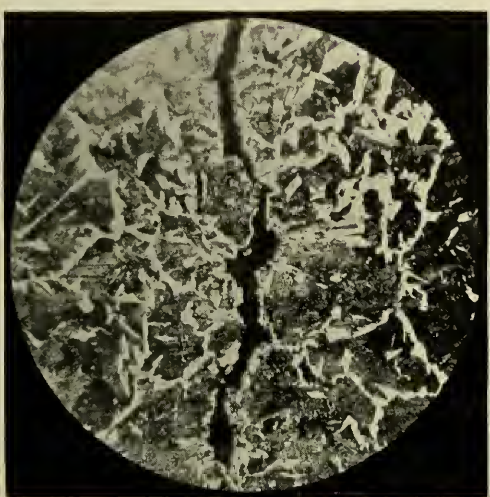


FIG. 24. Primitive State, before Straining.

FIG. 25. Appearance after having been Slightly Strained, a Fissure Opened along the Line of the Streak.

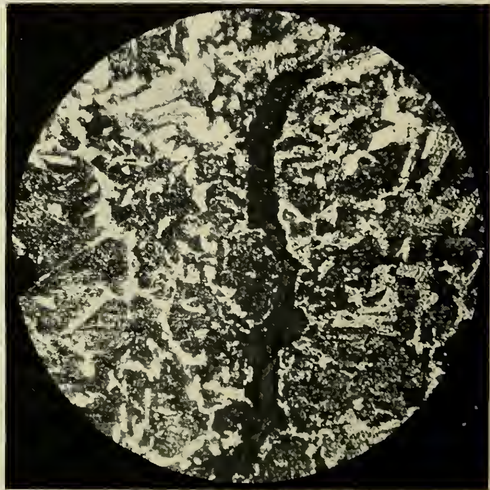


FIG. 26. Appearance after Further Straining, Increasing the Width of Fissure shown in Fig. 25.

Microstructure in Vicinity of Streak in Base of Rail. Magnification 150 Diameters.

The straining force was so slight as to hardly cause an appreciable permanent set in the base of the rail.

The same sample was bent again, a little further than on the former occasion, resulting in an enlargement of the fissure, as shown by Fig. 26. Dr. Henry Fay, in collaboration with the speaker, recognizes the material in this streak as manganese sulphide, and furthermore that the thermal cracks in the running surface of the rail previously referred to also passed through streaks of manganese sulphide.

From this it would seem that certain of the streaks are fissures in which there is lack of continuity of the steel, the narrow space between being occupied by a substance having little adhesion to the walls thereof.

DISCUSSION.

Mr. J. Parker Snow (*by letter*). — Rails fail in service in a variety of ways. Broken rails can generally be grouped into four classes:

1. Square break.
2. Crescent break and its derivatives.
3. Split head.
4. Split web.

Failed rails that do not actually break also show four groups:

A. Crushed head.
B. Flow of metal.
C. Shelly corner.
D. Worn head.

1. A break coming under the class of square breaks may be square or angular or curved so far as the relation of its surface to the axis of the rail goes. The line of the fracture across the base, however, is generally straight whether square across or at an angle with the line of the rail. Breaks under the drop test and in a testing machine, when loaded as a beam, are generally of this class. Anything that renders steel brittle, like coarse grain, high phosphorus, concentrated manganese, segregated carbon, the presence of oxides, silicates or sulphides, or the crushing of the metal by excessive wheel loads, skidded wheels or slipping drivers, will cause rails to break in this way, as well as loads that overcome the ultimate strength of the metal. In ordinary service at the present day these breaks are few.

2. The great majority of the broken rails that have occurred in this vicinity in recent years are of the crescent type. These

fractures start from a longitudinal flaw of some sort near the center of the base and run with the flaw, sometimes a fraction of an inch; sometimes as much as six feet and then break out to the edge of the flange in a crescent shaped curve. Sometimes one side only of the base breaks out and rails have been known to do service for years in this condition. Generally, however, a rail weakened in this manner breaks through the other flange, the web and the head, immediately. The break through the web and head are exactly like a square break. The fracture across the base is not a straight line as in the first class, but such as will leave a cusp point on one part of the base and a corresponding re-entrant angle on the other, oftentimes accompanied by a split along the prolongation of the seam that caused the fracture. It is generally possible to distinguish the flaw, at which the fracture started, as a smooth seam face, sometimes so open that it is strongly corroded, sometimes close and showing a bluish surface like mill scale, but sometimes granulated as though it had been weakly stuck together like a soldered joint. Sometimes these seams will be exactly vertical and may at the ends pinch out by passing upwards into the metal. Sometimes they are inclined to the vertical with their sides fluted and in this case they do not pass up into the metal at their ends. I may say that in all the cases of crescent breaks that I have examined, and that is a good many, it has always been possible to discern the manifest flaw from which the fracture started. A better name for this type of failure would be, perhaps, "split base," for the initial point of the break is a longitudinal split in the base.

3. Split heads have caused a great deal of trouble on some roads. One side of the head splits off nearly in the plane of the side of the web. The piece split off may be but a few inches long or it may be as much as ten feet long. Pipes in the ingots may cause some of these splits, but indications of seams in the heads are sometimes present, similar to those above described in the base. Split heads caused by these minute seams are probably brought about by what are known as progressive fractures. That is, the little flaw works downward under the blows and vibrations from the wheel loads and finally gets to the underside of the head and the piece drops off.

4. Split webs occur in considerable numbers in some regions. The web splits horizontally at the end of the rail, generally through the bolt holes. It is analogous to failure from longitudinal shear and is probably an indication of excessive internal strain due to unequal shrinkage of head and base in cooling.

A. Many rails fail by the so-called crushing of the head. On many lines carrying heavy equipment, this class of failure covers the majority of defective rails at the present time. In this type the head flattens and broadens out, the sides of the head generally sag down, decreasing the fishing angle, and if continued in use the head finally splits and slumps down.

B. When the metal on top of the head rolls out to the sides and forms an overhanging lip without any indication of a breaking up of the structure of the metal, it is called " flow of metal." Steel that shows this phenomenon is certainly ductile, but is not rigid enough to carry the wheel loads imposed.

C. Shelly corners produce a condition somewhat similar to flow of metal, but in this case there is certain evidence of unsound structure. The corner of the rail slumps down and frequently peels off. Rails with this defect are very common. They often show low spots on one or both corners, one to two inches long, scattered along the length of the rail, a few inches to several feet apart. Each and every one of these spots has an open seam under it. They appear to be due to seams like those producing split heads and crescent flange breaks.

D. Excessive and rapid wear of the gage side of the head by the wheel flange comes under the class of worn head. If unduly rapid and due to the quality of the steel, we can suspect segregation or unsoundness, due to the presence of undesirable oxides, silicates or sulphide, or coarse grain due to improper heat treatment.

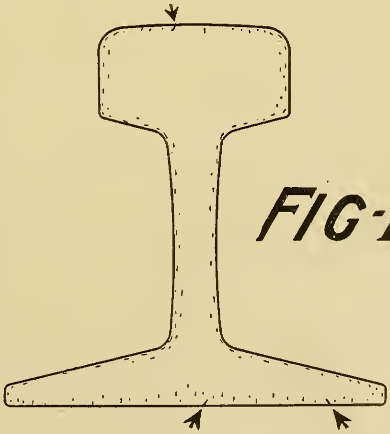


FIG-1

The author of the paper has shown us in a very instructive way some of the manifestations of unsoundness in our rail steel. To show how two kinds of these flaws appear to me in the actual rail, I submit Fig. 1. The short marks on the section are intended to represent actual fissures in the steel. Narrow lines represent the minute fissures accompanying light streaks which I have called in previous discussions " gas seams." The three broader lines indicated by arrowheads represent what I call

"rolling flaws." It is almost impossible to see these flaws in the cross-section of a rail without very high magnification, but they show very plainly when the metal is cut longitudinally at right angles to their planes. Considering, first, the gas seams: it will be noted that the lines are vertical in the lower portion of the base and top of head. At other points they are shown more or less parallel to the surface. The positions are conjectural to some extent, as I have not traced them entirely around the contour of the rail; but at the junction of the web and base they certainly follow the surface as indicated and are vertical in various other parts. They seem to lie parallel to the pressure of the rolls. But few of them reach the actual surface and they do not extend into the metal very deep, except sporadically. This distribution seems to follow that of the white streaks in the steel examined by Mr. Howard.

I call these flaws, gas seams, because they appear to follow the location and characteristics of gas bubbles that are so generally found in steel ingots. A zone of bubbles is almost invariably formed around the sides and across the bottom of steel ingots from 1½ to 6 in. from the outside. These are closed by the rolling, but cannot thoroughly weld. If parallel to the surface or deeply seated, say ½ in. from the outside of the rail, they do not seem to work much harm.

The subject of gas bubbles or blow holes in steel ingots was treated quite exhaustively by Mr. E. von Maltitz, metallurgical engineer of the Illinois Steel Company, in a paper before the Institute of Mining Engineers in July, 1907, wherein he shows that where recarbonizing is done in the ladle and insufficient time allowed for the complete reduction of the iron oxide in the bath, an excessive number of gas holes may be formed. Moreover, the manganese protoxide, silicates and sulphides formed by this reduction may not have time to separate into the slag before the steel reaches the mold. In this case small nodules of these manganese salts may occur as inclosures in the metal, rendering it brittle. Such inclusions may be expected, then, in connection with gas holes, as was shown by the microphotographs on the screen.

The three flaws of Fig. 1 (marked by arrowheads) will be seen to be wholly at the surface of the metal and to be few in number. They are frequently inclined to the surface and are more or less crooked when viewed in plan, whereas the gas seams are remarkably straight and true. When opened up, their surfaces are always smooth, precluding the possibility of their ever

having been stuck together. Sometimes they are so open that they can be traced on the base before the rail is laid. In this case when broken their sides are well rusted. Sometimes they are so close that they do not corrode and when opened their sides are bluish like mill scale. Their line is generally somewhat crooked and their sides are often fluted longitudinally. I call them rolling flaws, because I believe they are the product of surface defects in the ingot or bloom. It is well known that shrinkage cracks or checks occur in the skin of ingots and that tears occur in the surface of blooms during the early passes through the rolls. Formerly these checks and flaws were carefully chipped out before rolling was proceeded with, but for a decade or more this precaution has been omitted at most mills because it was found that such wounds would close up in the rolling process and lead to but very few rejections.

I have seen at Mr. Howard's laboratory a slice from an ingot with a shrinkage crack more than 6 in. long and $\frac{3}{4}$ in. deep. What would become of this when rolled out into a rail? It would not weld. It is a ragged, irregular opening and would roll into a more or less crooked seam. The metal might be crowded sideways, so that its plane would become inclined and perhaps curved and the roughness of the original would result in flutings and striae such as these defects show. It seems to me the genesis is complete.

A third element of unsoundness in rails, not shown in Fig. 1, is exhibited by the dark streaks found in the deeper cuts in the metal. These do not show on the polished surface unless etched. They show finely in cross-section and seem to be closely allied to segregation. The inclusions of manganese salts, mentioned above, may be a part of the galaxy of dark streaks, leading to the familiar figure so often illustrated in rail sections. Segregation is inevitable in the solidification of steel, and if normal can be so disposed of as to cause but little trouble.

Can we now correlate our various types of failed rails with the three classes of defects that stand confessed in the steel of which they are made?

1. Square breaks can hardly be charged to any of these defective features. They are probably due to accidentally high carbon or phosphorus or to service conditions beyond the capacity of the rail. Steel loaded so as to cause a change in its structure, as shown on several of Mr. Howard's slides, renders rails peculiarly liable to square breaks. Such indications show the limit of wheel loads for carbon steels.

2. Crescent breaks, or more properly split bases, I believe to be due to longitudinal weakness in the rail as rolled. A rail is supposed to be supported by the tie uniformly across the width of its base. The load comes to the center of the base through the web. These forces produce a moment tending to split the base longitudinally. If the metal is sound, the strains set up are not great enough to produce fracture or even distortion; but if the base is full of incipient seams, fracture will naturally follow. The fiber strain, produced by the moment referred to, is greatest at the center of the base. We find most of the fractures starting from the center or just under the side of the web, and although the examinations described by Mr. Howard show us that there are seams across the whole width of the base and throughout the metal of the base, it is the seams near the center that determine the fracture.

My examination of these breaks leads me to think that rolling flaws lead to far more failures than gas seams or streaks of included salts of manganese. My reason for this conclusion is that invariably a smooth seam-face, characteristic of rolling flaws, is discernible at the initial point on the corner of the break of the crescent broken out.

If rolling flaws and surface gas seams are not the predisposing features that actually lead to these breaks they are certainly competent to do so, and their elimination or proper control is greatly to be desired.

3. Split heads may be, and I believe are, caused by the same class of flaws as base breaks. The actions of the wheel load and web are the same as described above, except that the lever arm producing the moment is much less. How can the head be expected to hold together when it contains open fissures such as Mr. Howard's investigation has revealed? Pipes and wide plates of included sulphides lead to some failures of this class without doubt, but the diagnosis given here and in the previous paragraph 3 appears to me more widely applicable.

4. Split webs are not attributable to any of the three classes of defects described above. They are probably due to a condition of internal strain that would be wholly removed by annealing if that was practicable.

As to the four groups of rails that fail without breaking:

Group *A*. Crushed heads can be traced directly to unsound metal. Mr. Robert Job, while chemist of the Philadelphia & Reading Railway, studied this matter thoroughly and discussed it many times. He showed that in every failure of this sort a

polished end section showed marked unsoundness. Excessive segregation and veins of manganese salts, shown on the screen as dark streaks, render the metal liable to rapid crushing. It is evident, too, that a wilderness of vertical flaws like the gas seams shown on our Fig. 1 will weaken the head greatly. In fact, Mr. Job says that unwelded seams near the surface of the head cause far more failure than segregation.

B. Flow of metal occurs, of course, when the rail is too soft; but improper heat treatment at the mill, such as will cause the grain to be coarse, is the usual cause of this defect. One reason for the magnificent service of early English steel rails is the fine, even texture of the metal. John Brown rails, although full of segregation streaks and of execrable chemistry, do not flow because the texture of the metal is fine.

C. Shelly corners can be traced directly to gas seams or veins of manganese salts, parallel to the surface at the corner of the rail. Sound rails do not give way at the corners, but metal containing these seams cannot stand the severe torsional shearing imposed by the wheels of heavy equipment at high speed.

D. Worn heads must be expected to a reasonable extent. It is only those that wear unduly fast that can be attributed to defective steel. Coarse structure due to hot finishing is certainly deleterious, but the three metallurgical defects that we have been discussing can hardly be charged with this type of deterioration.

Hence, of the eight types of broken and failed rails, we can claim four, viz., crescent breaks, split heads, crushed heads and shelly corners, as due to structural defects in the steel. It is probable that there never has been a perfectly sound rail rolled; and, what is more, it will probably be impossible to ever produce a rail from melt-made steel that will be wholly free from internal defects. With all the flaws that have been shown to be so common, it is likely that a thousand rails give satisfactory service to every one that fails. This means that these defects can be tolerated if kept within proper bounds. The studies so far made at Watertown Arsenal have shown us the nature of many of the defects. We hope that further study will show us the cause of these defects. Then it will be in order to study methods for obviating the causes.

In my opinion gas seams and rolling flaws are far more vicious in their effects than segregation or inclusions of manganese salts.

Mr. Job claims that if these defects are kept well within the

metal, say ½ in. from the surface, they will do but little injury. Mr. von Maltitz shows in his paper, referred to above, how gas bubbles can be controlled and prevented from forming near the surface of the ingot; so that by proper manipulation of the melted steel it seems possible to eliminate gas seams from the list of dangerous defects. Rolling flaws, the most dangerous of all seams, are necessarily on the surface. They are due to cracks in the skin of the ingots or blooms, or to folds in the metal, while it is being rolled. Many cracks occur in the blooms due to heavy reduction. This certainly can be obviated; shrinkage checks in the ingots can be chipped out; and folds can be prevented by careful reductions in the rail train. The absence of crescent breaks in John Brown rails is due, no doubt, to the fact that careful rolling produced no rolling flaws. If rails could be rolled without these flaws forty years ago, they can be rolled so now.

If seams are present, but have their planes parallel to the surface, as occurs on the top side of a rail base and in plates and shapes of structural steel, but little trouble arises from them. If rails could be formed in a Gray mill, as appears possible, the plane of gas seams, at least, would be so disposed. The finishing pass of a blank so rolled could be made in a grooved roll.

Inclusions of manganese salts can be controlled, and mostly prevented, according to von Maltitz, by using care not to overoxidize the bath and by giving time for these salts to rise into the slag before the charge is teemed into the molds. Dr. P. H. Dudley, of the New York Central, requires a definite interval of time between the additions of the spiegel and the teeming of the steel.

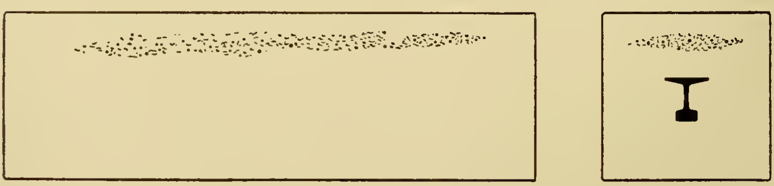
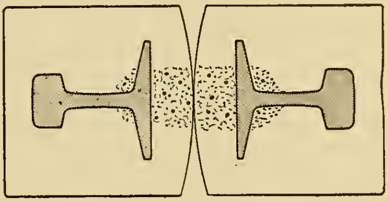


FIG-2

As to segregation, a considerable number of years ago it was the custom at some mills to throw the ingots on their side for charging into the soaking furnace. This caused the segregate to form along the top side of the ingot as indicated in Fig. 2. The mass was then handled in such a way that the base of the rail was

formed from the segregation side, as shown in the figure. This left the head practically free from segregated material. Ingots are now kept on end until they go into the blooming rolls. The segregate is consequently central in the mass and the sections that have been shown on the screen prove that the segregate is in both the head and the flange. If an ingot is rolled into a slab and sheared lengthwise into two billets, as indicated by Fig. 3, and the billets passed to the rail train, so that the base is formed from what was the central part of the ingot, the heads will be formed of metal practically free from segregate. The figure shows the relative position of the rails.



FIG·3

There is very much in the metallurgy and manufacture of rails not touched upon in this paper. I have dealt only with common failures in rails and the manifest defects in the steel that render rails so liable to these failures. The suggested remedies are so obvious and so simple in application that the continued production of such defective rails as have been furnished during the present decade seems to me a disgrace to American industry.

PROF. HENRY FAY. — Last summer and winter there was so much in the papers about the breakage of steel rails that it occurred to me there was probably something still to be learned in regard to the cause of such breakage. I determined, last winter, to make some investigation along that line, and since the 1st of January I have been engaged with one of my students on this subject, and personally I have been associated with Mr. Howard in some of his work and have reached some important conclusions.

I must differ, I think, from Mr. Snow as to his conclusions in regard to the importance of what he calls manganese salts. The reason why I can't agree with Mr. Snow, I want to tell you. The first piece of rail I examined was a small piece, broken out or knocked out by a hammer, which showed a check, the check being smooth and entirely different from the crack or fracture. The photograph clearly shows this. The metal was cut through about one-quarter of an inch away from this check, polished, and examined under the microscope. On the same line with the check was a long streak of manganese sulphide extended in the

direction of the rolling. Photograph No. 2 illustrates this appearance in a long, thin line. That evidently produced the check; but we hadn't sufficient evidence to say that it did. I then proceeded to examine a number of crescent breaks, and to my surprise found they were invariably associated with a very large amount of manganese sulphide.

I want to tell you something in regard to the character of manganese sulphide. Manganese sulphide melts at 1162° cent. Its specific gravity is 3.96 or about half that of steel. It is a glassy, hard, extremely brittle material. The steel from which the rail is made solidifies at about 1450° cent. and the manganese sulphide will not solidify until it reaches 1162°. Therefore, the manganese sulphide is in a fluid state some time after the steel solidifies. If the rolling of the rail starts, we will say, at a temperature above 1162°, this material will be rolled out in thin strips in the direction of rolling. It is plastic below the melting point and it is capable of being rolled out while in the plastic condition into long, thin strips. Manganese sulphide may not be the cause of all crescent breaks, but if we take into consideration in this connection the fact that you can predict where a break is going to occur, and say that a break will occur along the line of manganese sulphide, I think the evidence is almost conclusive.

Mr. Howard has shown one or two figures in which the crack followed through the manganese sulphide. That would not have been so remarkable if it had not been predicted beforehand that the break would occur through this area. This prediction I made, and the crack occurred as predicted. More recently I have shown in the work with Mr. Wint, at the Institute of Technology laboratory, that metal cut from crescent breaks when strained will start cracks every time through the manganese sulphide before a crack starts in any other part of the metal. In all cases examined the metal shows very little ductility, and I think that is good evidence that we have an extremely brittle material. I do not think the importance of the observation that cracks will begin in manganese sulphide areas can be overestimated, and I believe the remedy is simple.

The cause of the manganese sulphide being in the steel is comparatively simple. When the spiegel or ferro-manganese is added to the molten metal after the blow, the manganese combines with the sulphur and, given time enough, manganese sulphide, having a specific gravity less than that of steel, will rise to the surface. Give it more time and it will purify itself.

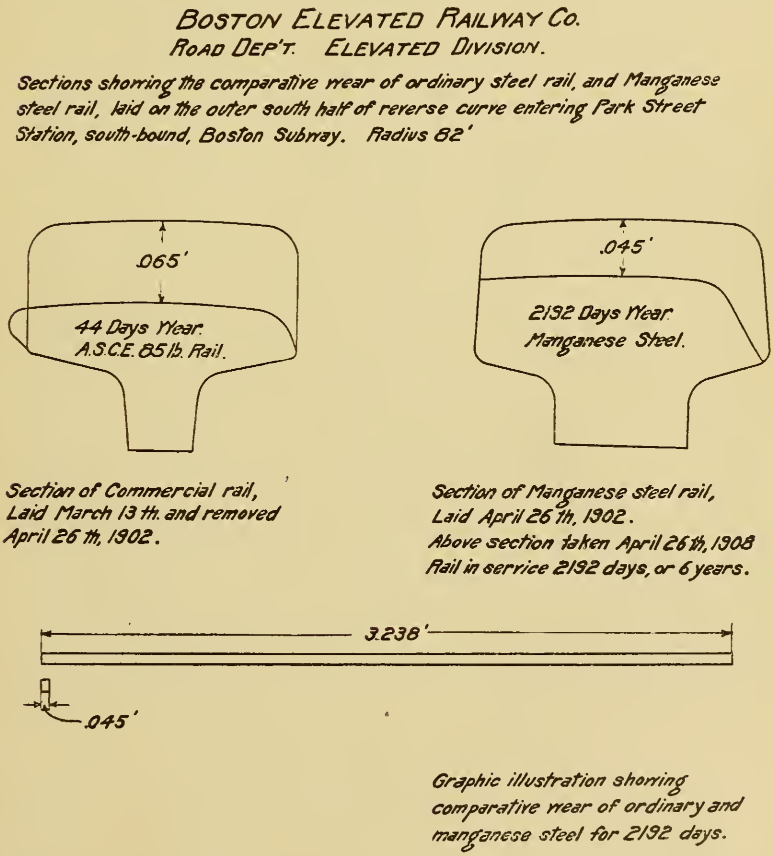
FIG. 1.

FIG. 2.

Mr. Parker. — We have heard much about phosphorus, and I understand that the Pennsylvania Road has given up the use of Bessemer steel because they found that phosphate ore is exhausted.

The President. — Can anybody explain what Mr. Parker wants to know about phosphorus?

Professor Fay. — I might say that the Pennsylvania Road has not ceased to use Bessemer steel, but in their new specifications they call for not more than 0.1 of 1 per cent. of phosphorus. In a Bessemer rail they allow, I think, 0.55 per cent. of carbon and not over 0.1 per cent. of phosphorus. In open-hearth material, where there is less phosphorus, more carbon is allowed.



Mr. George A. Kimball. — I have been very much interested while listening to these valuable papers, and the remarks which have followed have also been very instructive. The Bos-

ton Elevated Railway, with which I am connected, has purchased a large quantity of steel rails from time to time. We have not had a very large number of broken rails, but the rails wear very rapidly on our sharp curves. On one curve of 82 ft. radius in the subway the ordinary rail was worn out in 44 days under a heavy traffic, while other harder rails wore a little longer. After several renewals with ordinary rails, it was decided to use a manganese rail, which has been very successful, and has now been in service about six years. I have invited our road master, Harry M. Steward, C. E., to be present this evening, and to speak on this question. He is thoroughly acquainted with the wear of the several kinds of rails on our elevated division. I present a view of the curve in the subway, and also a diagram showing the wear of the ordinary rail and the manganese rail.

Mr. Harry M. Steward. — I cannot say much about broken rails; we do not have many, as our equipment is not as heavy as that on steam railroads.

Mr. Kimball is right about rails not lasting on the Park Street curve. They used to wear out on an average in 44 days, while the manganese steel rail referred to has been in service over six years. This particular manganese rail is not rolled, but cast. I believe, however, there is a movement on foot by various steel companies to roll manganese steel rail, which I understand is a very difficult thing to do. We have been urged to try rolled manganese rail for some time and we hope to do so. I hope it will be found possible to roll such rail, as cast manganese steel is not the best thing that can be produced, for the very reason of its being cast. The wearing qualities are something to be proud of, to be sure, but the price is very high. For instance, rolled rail costs about 38 cents per running foot, while, last year, manganese rail cost us from $6.50 to $9.00 per running foot. This high cost is not so much in the actual worth of the metal as in the finishing of the rails. The rails are cast in about 20 ft. lengths and after being taken out of the molds have to be straightened and then ground to shape. No machine tool, such as a planer, can be used. Grinding is a very slow process, and on account of the labor necessary to shape the rails, the price is very high. If manganese steel rail can be rolled, it can be made use of to a great extent on the Boston Elevated Railway and many similar roads.

Mr. Kimball. — Will the manganese rail resist the side wear the same as the top wear?

Mr. Steward. — We have found that manganese steel will

Boston Subway. Looking South on South-bound Track, just North of Park Street Station.

not withstand side wear as well as top wear. The rolling friction on the top does not seem to have the same effect on the metal as the cutting or grinding friction of the wheel flanges on the side of the rail, and consequently we do not allow the rail to get as much side wear. We protect it, as we do all rails on the outside of curves, by a heavy guard rail which can be greased and which is attached to the inner rail of the curve.

The President. — I would like to ask Mr. Steward if he can give us the chemical composition of that manganese steel.

Mr. Steward. — I cannot tell you the composition, although I understand it is no secret, but there is a secret process in its manufacture which is in the treatment of the steel after it is cast. After the rail has been cast it is reheated in a furnace and quenched at a certain heat. This, and other portions of the treatment, are very carefully guarded. I think that the percentage of manganese is very high, anywhere from 8 to 14 per cent. The other elements are about the same, I think, as ordinary Bessemer or open-hearth rail.

A Member. — Mr. Steward, can you tell us whether the paper on manganese rails which was read before the Street Railway Club is published in their proceedings? The paper was read three or four years ago and dealt with manganese rails. Can you tell us whether it was published?

Mr. Steward. — I believe I read a paper three or four years ago, but not particularly on manganese rails.

Member. — Did Mr. Wharton read a paper?

Mr. Steward. — No, but Mr. Angerer, general manager for the Wharton Company, did.

[Note. — Further discussion on this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by September 15, 1908, for publication in a subsequent number of the Journal.]

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THE SCHOTT SYSTEMS OF CENTRAL STATION HEATING.

BY J. C. HORNUNG.

[Read before the Society, May 15, 1908.]

BY way of introduction of the subject before the Society this evening I will first give a very brief history of central station heating, of both steam and hot water, especially as applied to the art from a practical commercial standpoint.

Steam, under varying pressures, and from various sources, has been used for house warming a great many years, and this kind of steam heating is pretty generally understood, but exhaust steam as applied to the heating of more than one building, or, to speak more correctly, as supplied from a central station, has been in practical use for a period of about thirty years, and then only in a more or less limited way.

The system as brought out about thirty years ago was then known as the Holly System. Limited as was the territory which was then attempted to be covered, many difficulties at once became apparent, principal among which were the loss through the pipes by radiation, the linear expansion and contraction of the pipe lines, due to the wide range of temperatures within the pipes, and the pressures required to produce circulation. All of these difficulties have been overcome; some entirely, and others to a point where they are no longer considered serious.

Heating from a central station by utilizing the exhaust steam and transferring the latent heat units to water, which becomes the heating medium, was first tried on a commercial basis along in the nineties by Homer T. Yaryan, of Toledo, Ohio.

His scheme was simply to conduct the exhaust steam from a reciprocating engine to a surface condenser, thereby transferring the heat to the water, which, by means of pumps, was kept in constant circulation through the radiators. This method called for two pipes of equal size, which were laid side by side in the trench, the one serving as a heat-carrying pipe and the other as a pipe to carry the water back to the plant for reheating. Each building was connected in parallel on the mains similar to the parallel system of commercial lighting of to-day, the drop in temperature due to the house-warming coils being analogous to the drop in potential between the two wires.

About this time a one-pipe system of hot-water heating was brought out which was an enlargement of the systems commonly in use within the buildings; that is, a single pipe belt was run around a block and the various buildings were shunted off the belt similarly to the arc-lighting systems in common use to-day. This system requires that the pipe shall be of the same size throughout the belt, and the number of heat units which can be supplied is determined by the allowable drop in temperature between supply and return ends of belt; as in arc lighting when one belt is loaded an additional belt may be run from the power-house.

In 1897, Mr. W. H. Schott saw the possibilities of central station heating and developed first the *balanced column system* of hot-water heating and a year or two later the *regulated steam system*. From time to time variations from the systems already mentioned have been attempted, but weakness in designs and lack of determination to perfect have caused a withdrawal from the field.

The paper will now take up the Schott Systems, viz., the Balanced Column Hot-Water System and the Regulated Steam System, of which the steam system is at present being installed in Salt Lake City.

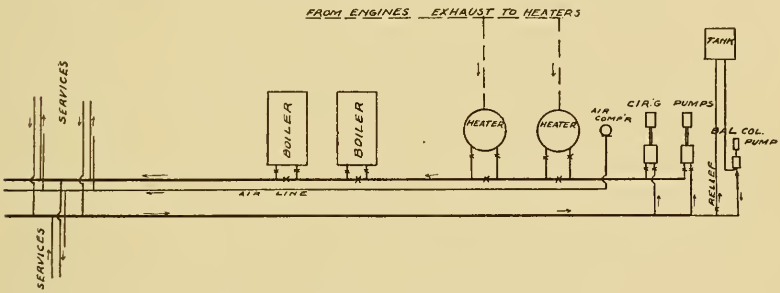
For convenience, and since the fundamental principles were worked out from a water standpoint, we will first consider the hot-water system.

The general station arrangement of this system is shown in a conventional way as indicated by Fig. 1. The exhaust from any steam engine enters the heaters or condensers, which are of the surface type and built in such a manner that the exhaust does not come in contact with the circulating water. As a matter of fact, the condensers do not differ in their functions from a condenser used in a standard condensing power plant, except that

instead of circulating the water through cooling towers, thereby dissipating the heat, we circulate it through house warming coils.

The condensers are usually connected so that no back pressure comes upon the engine, and the water of condensation is handled by a tank receiver pump which delivers it automatically to an overhead tank and from which it again flows by gravity to the feed water heater. An even and accurate supply and temperature of feed water is hereby made possible.

When the situation warrants, a vacuum pump may be placed on the condensers and operated at vacuums which are inversely proportional to the temperature required in the circulating water. Another advantage of this feature, where cooling water may be had during the summer, is that the station equipment of the heating system may be kept in commission throughout the year.



THE SCHOTT "BALANCED COLUMN" HOT WATER SYSTEM.

FIG. I.

The water of condensation with some make-up water is also used for keeping the distributing system filled, thereby avoiding the annoyance of scaling in the pipes and radiators, which, in the early state of development, was a serious trouble.

The separation of the cylinder oil from the steam is, of course, taken care of before steam enters condensers by the use of efficient oil separators.

The circulating pumps, which are usually of the piston type on a two-pipe system, are automatically controlled on the steam inlet so that a constant pressure is maintained, and, in conjunction with the house temperature controllers, operate to avoid any excess pumpage, which naturally tends toward greater capacity and the elimination of wasted heat units.

Centrifugal pumps of the ordinary type have not been brought into general use on account of varying conditions imposed; that is, varying pressures due to varying loads or elevations and varying quantities of water required due to varying

temperatures. This applies to a two-pipe system and clearly demonstrates that automatic regulation is highly essential where heat is sold on a flat basis and this, by the way, is the only basis for hot-water heating to-day, as no one has so far been able to devise a successful means for measuring this service.

An interesting pumpage chart may be plotted for any given 24 hours. Observation of such chart would show that during the night hours the pumpage is lowest and that during the morning hours, when doors and windows are thrown open, the pumpage increases until about ten o'clock, when it again decreases until evening, when another increase appears. This applies when the outside temperature is normal, but now we have another and much more severe condition to meet, and that is the sudden fluctuation in outside temperatures. Our records show that a drop of 40 degrees in less than one hour is not uncommon, and on such occasions the acceleration in speed of pumps, and incidentally of the firemen, is, indeed, interesting to note.

The efficiency of centrifugal pumps over piston pumps is, of course, fully established, but since the exhaust which has lost none of its latent heat units is at once passed on to the condensers, the net efficiency is not different to any degree.

The boilers as shown are simply the steam boilers employed in any power or electric plant and are connected so that at will they may be converted into circulating boilers. This change requires about twenty minutes, and with it the highest efficiency is obtained, where it is necessary to make up a deficit with coal direct when exhaust is insufficient, due to the fact that boilers operate under low tube and stack temperatures; virtually, they become economizers.

The air compressor is of the locomotive type and supplies approximately 15 lb. of air to the thermostats, which operate the individual temperature controllers placed on each of the several buildings on the line. The detail of these regulators will be taken up later.

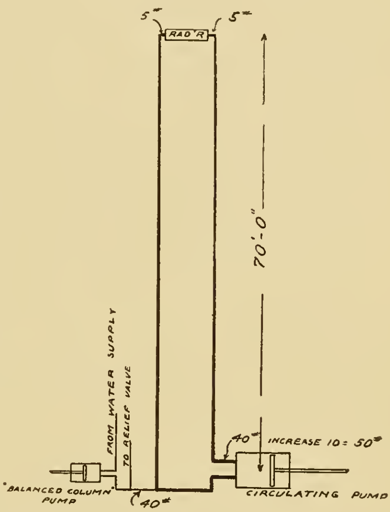
Follow now the circulation from the pumps through the condensers, which may be cut in or out; then to boilers, which may be by-passed or cut in series; then on to the houses which are connected across the mains; water passing through a given house but once before returning to the station for reheating.

The limit of business can at once be seen to be governed entirely by the size of mains and the heat-generating capacity at the station. Distance is governed only by the investor. Two miles distant is not uncommon, and greater distances are prac-

ticable. A drop of 1 degree in temperature in 1 mile of pipe line ordinarily represents the loss.

Following the return pipe back to the station, it will be noted that it connects direct to suction of pump with no other connection save the balance column pump and relief valve.

Fig. 2 shows the principle of the "Balanced Column." Essentially this system is a closed system so that one leg of the pipe line balances the other, and in practice the circulating pumps are required to overcome the friction in the lines only, while the balanced column pump simply maintains the static pressure in the return leg by keeping the system full of water. This item in a tight system is naturally very small.



THE SCHOTT "BALANCED COLUMN" HOT WATER SYSTEM

FIG. 2.

The elevation of 70 ft., as shown, may be in a mile or more of pipe and the "radiator" may represent several hundred thousand feet of radiating surface scattered over a wide territory. The relief valve is usually connected to a branch pipe of small diameter and the discharge flows back into supply tank. This valve operates only when the water expands, due to the rise in the temperature when more heat is required.

Automatic control of temperature in the various buildings is obtained by placing the main control valve in the return pipe just before it leaves the building. The valve is operated by valve stem which is attached to a diaphragm and this in turn is operated by air pressure supplied from the central station. The amount of air supplied, and hence the position of valve stem is controlled by a thermostatic device placed at a convenient place on an inside wall. When the temperature tends to rise above a predetermined point the air is simply allowed by the thermostat to act upon the diaphragm, and when the temperature tends to fall the thermostat relieves the air pressure, allowing the valve to open. Very close regulation is in this way obtained and

according to various tests made the reduction in pumpage will average about 30 per cent.

For practical purposes and to aid in design, a schedule of boiler capacities at varying outside temperatures has been carefully worked out. Take, for instance, 40 degrees above zero, which is an average temperature point, and with water circulating at 150 degrees, a water tube boiler of 100 h. p. rating will handle 36 500 sq. ft. of radiation. A fire tube boiler will handle 31 000 sq. ft. and a surface condenser, using exhaust steam, will handle 19 200 sq. ft. At 0 degrees, which is an average low temperature point, with water circulating at 200 degrees, the machines will handle 20 000, 17 400 and 11 500 sq. ft. respectively. For steam heating the boiler capacities will run from 5 to 6 per cent. less, due to higher tube and stack temperatures.

The amount of radiation which can be carried on any given line depends on a great number of conditions, principal among which are size, length, turns, elevations and class of service. However, in general practice an 8-in. line will carry 52 315 sq. ft. at a water velocity of 250 ft. per second and at a loss of 0.5 lb. pressure in 100 ft.

The service pipes for both hot-water and steam heating are usually graded toward the mains and for, say, 2 in. service, 100 ft. long, 3 000 sq. ft. of water radiation can be handled, while the same service for steam will handle 424 sq. ft.

The insulation of the heating mains against loss of heat by radiation is probably the most important feature in connection with the distributing system and hence several schemes have been adopted to limit this loss. Layers of wood with air cells between filled with an adaptable non-conductor have been successfully used for some years. The wood insulation, which is ordinarily of No. 1 hemlock, gives very high efficiencies and under normal conditions a long life. The general tendency now-a-days being toward greatest permanency, a concrete conduit has now been adopted, and with an approved filler, usually of asbestos, properly filled around the pipe, we get an insulation which is absolutely permanent and highly efficient. The insulation proper being largely in the filler, the greater requirements of steam as compared with water are met by leaving more space to fill.

When the soil is wet an effective underdrain is necessary to prevent moisture from coming in contact with pipes, as this undoubtedly has been one of the most serious difficulties in operating a heating plant successfully.

ERRATUM

Page 38, line 19. For *second* read *minute*.

Expansion and contraction of pipe lines during the heating season are factors of interest, since for every 100 ft. of line a travel of at least 2 in. must be allowed for. Taking a Salt Lake block, for instance (792 ft.), we have about 15 in. more pipe in a block in winter than we have in summer. The differences are taken care of with metallic packed joints of special design: for hot water, about 400 ft. apart, and for steam, about 150 ft. apart, each joint being placed in an accessible manhole. In steam practice all fittings and valves are flanged, and services are taken off only at points where fittings are accessible.

Concerning the coal consumption per square foot of radiating surface per hour, per day and per heating season, some very interesting data have been gathered and compiled from many plants scattered throughout Ohio and Indiana.

TABLE 3.

COAL CONSUMPTION AT VARIOUS TEMPERATURES

SEASON OF 5280 HOURS — INDIANA SLACK COAL - 10500 B.T.U.

EFFICIENCY = 60% — TEMPERATURE OF ROOM 70°

MEAN TEMPERATURE OF WATER	OUTSIDE TEMPERATURE	HEAT UNITS PER HOUR	HEAT UNITS PER DAY	HEAT UNITS PER SEASON	POUNDS COAL PER HOUR	POUNDS COAL PER DAY	POUNDS COAL PER SEASON
220°	-30°	306	7344	1615680	.047	1.128	248.16
212°	-22°	280	6720	1478,400	.044	1.056	232.32
210°	-20°	275	6600	1,452,000	.0437	1.049	230.74
200°	-10°	246	5904	1,298,880	.0390	.936	205.92
190°	0°	221	5304	1,168,880	.0351	.842	185.32
180°	10°	195	4680	1,029,600	.0310	.744	163.68
170°	20°	170	4080	897,600	.0270	.648	142.56
160°	30°	146	3504	770.880	.0232	.556	122.32
155°	35°	136	3264	719,180	.0216	.518	114.05
150°	40°	124	2976	654,720	.0197	.472	103.84
140°	45°	102	2448	538,560	.0162	.388	85.36
130°	50°	82	1968	432,960	.013	.312	68.64
120°	55°	66	1584	355,480	.0104	.249	54.78
110°	60°	51	1224	269,280	.0081	.194	42.68
100°	65°	44	1056	232,320	.0070	.168	36.96

Table 3 shows results from Indiana slack, based on a season of 5 280 hours at a net efficiency of 60 per cent. That is, 60 per cent. of the total calorific value of the coal was delivered by the radiator. The radiating surface in this case was the ordinary cast-iron bronzed radiation, mostly of standard heights.

One of the most difficult problems in central station hot-water heating is the accurate determination of the amount of radiation to be set in any given room or building. This is due to the fact that the consumers pay on the number of feet set and

the producer must guarantee temperatures. Either a slight excess or insufficiency will naturally cause complaint. The result, however, of this extreme care is satisfactory, since the consumer is given a service which cannot be excelled.

In arriving at radiation requirements some interesting results are obtained, one in particular as concerns the standard cast-iron radiator, viz.: At a mean internal temperature of 170 degrees and an external temperature of 70 degrees the surface will emit 170 B.t.u. per square foot per hour, but for any increase or decrease in mean internal temperatures there is a logarithmic rather than a proportional increase in heat emitted. However, it is possible to plot curves from which, for any given internal temperatures, the heat emitted can be determined. It is also possible to plot curves for heat transmission through glass or exposed walls, and with these data tables may be compiled for any requirements met in commercial practice.

TABLE 4.

CENTRAL STATION COEFFICIENTS "A"

Based upon 6" Water per ☐ Radiation per hour. Water entering Radiator at 212° and leaving at 175°. Decorated Radiator emitting 225 B.T.U. per sq. ft. per hour, at 70°. Mean temperature of Radiator, 190° at 20° below 0.

KIND OF SURFACE	TEMPERATURE OF ROOM							
	55°	60°	65°	70°	75°	80°	85°	90°
Single glass, loose	.58	.64	.69	.73	.77	81	.85	.90
" " tight	.48	.53	.57	.60	.64	68	.72	.75
Vault light glass	.57	.63	.68	.72	.76	.80	.84	.89
Single skylight	.42	.455	.49	.52	.55	.59	.62	.65
Double "	.24	.26	.28	.30	.32	.34	.36	.38
Good Door, ½ Glass	.26	.28	.30	.32	.34	.36	.38	.40
Double Glass (Storm Windows)	.225	.24	.26	.28	.30	.32	.34	.36
Average Frame N. & W.	.175	.19	.20	.22	.23	.24	.26	.27
" " S. & E.	.16	.175	.18	.20	.21	.22	.24	.25
8" Brick Wall or Well Constructed Frame N. & W.	.16	.175	.19	.20	.21	.22	.24	.25
8" Brick Wall or Well Constructed Frame S. & E.	.155	.16	.17	.18	.19	.20	.22	.23
Back Plastered Frame N. & W.	.13	.14	.15	.16	.17	.18	.19	.20
" " S. & E.	.11	.12	.13	.14	.15	.16	.17	.18
12" Brick Wall N. & W.	.11	.12	.13	.14	.15	.16	.17	.18
" " " S. & E.	.09	.10	.11	.12	.13	.14	.15	.16
17" " " N. & W.	.09	.10	.11	.12	.13	.14	.15	.16
" " " S. & E.	.07	.08	.09	.10	.11	.12	.13	.14
Ordinary Floor or Ceiling	.04	.0425	.045	.048	.05	.053	.057	.06
Fire Proof "	.02	.0225	.025	.0275	.03	.0325	.034	.035

Consider Floor when Basement Piping is covered or Basement is not otherwise heated, and if Basement is not tight add 10% to 25%.
Consider Ceiling if Attic is unfloored or otherwise unprotected.
If Rooms or Halls are open to Attic or other open unheated space add 10% to 50%
When Building is exposed to severe winds add 10% to 25%
Multiply by .6 for Steam Systems.

To find the radiation required to take care of the cubic contents of a room is largely a matter of judgment on the part of the engineer, as it is wholly a matter of determining how many changes of air per hour may take place, which number of changes may, to some extent, be predetermined, as in mechanically ventilated rooms, but more often, as in residences, it depends

upon the general construction of building and tightness of windows.

Tables 4 and 5 give coefficients for glass, exposed walls and cubic contents which have demonstrated their accuracy.

TABLE 5.

CENTRAL STATION COEFFICIENTS "B"

Based upon 6# of Water per ft of Radiation per hour.
Water entering Radiator at 212° and leaving at 175°.
Decorated Radiator emitting 225 B.T.U. per # per hour at 70°
Mean temperature of Radiator, 190° at 20° below 0.

CHANGES OF AIR PER HR	TEMPERATURE OF ROOM							
	55°	60°	65°	70°	75°	80°	85°	90°
½	.003	.0032	.0034	.0037	.0039	.0042	.0043	.0045
1	.006	0064	.0068	.0075	.0077	.0083	.0086	.009
1½	.009	.0096	.0102	.011	.0115	.0125	.0129	.0135
2	.012	.0128	.0136	.0146	.0154	.0166	0172	.018
2½	.015	.016	.0172	0183	.0192	.0208	.0215	.0225
3	.018	.0192	.0206	.0219	.0228	.0249	.0258	.027
3½	.021	.0224	0240	.0255	.0264	.0291	.030	.0315
4	.024	0256	.0274	0291	.030	.0332	.034	036
4½	.027	.0288	.0306	.0333	.0351	.0378	.0387	.0405
5	.030	.0320	.0340	.0365	.0385	0415	.0430	.045
5½	.033	.0352	.0374	.0407	0429	.0462	.0473	.0495
6	.036	.0384	.0408	.0438	.0462	.0498	.0516	.054

Multiply by .6 for Steam Systems

Concerning the steam-heating plant which is at present being installed in Salt Lake City, we have, for generating electrical current, the two-stage vertical turbines taking steam at 150 lb. pressure. The steam for heating purposes is taken from the first stage of the turbines and carried through a 16-in. low-pressure main to a well-established center of distribution which is located in the heart of the commercial district.

The steam passes from turbine to heating main through an automatic regulating valve, specially designed, and capable of adjustment for delivery pressure varying from 0 to the initial pressure, and at such predetermined adjustment will hold the delivery pressure constant regardless of variation in the initial or turbine pressure. Direct from the high-pressure steam header in the station is run a 6 in. line which feeds directly into the center of distribution, and from this center is also carried a small pressure-indicating line back to power house so that the attendant knows at all times what his up-town pressures are.

There is also a high-pressure injector of special design placed in the low-pressure main where it leaves the power house, so that when the turbines are running light a small deficit may be sup-

plied without putting into operation the high-pressure line. This injector is so designed as to put no increased pressure on the turbines. One feature of this system is that the turbines run condensing on the second stage the same as though the first stage had been normally operated.

The condensation after passing through the meters is returned to the station from such territory as lies above the plant. Otherwise it is turned through cooling coils into the sewer.

The regulation of heat in the various buildings is handled the same as for hot water, except that in the case of steam the main controlling valve is placed on the supply pipe as it enters the building.

To meet the growing demands for a more complete service, the Schott Systems have devised their own air valves, condensation meters and low-pressure traps.

The air valve is known as the AUTO-VAC valve and, stated briefly, it allows air to escape from the radiator but no steam or water, and it allows no air to return to the radiator through the valve. In construction it is simply a brass case containing a diaphragm, a check valve and a generous float which floats in water and expands in steam.

The meter is known as the COMBI RECORDING STEAM TRAP, since it acts as a trap as well as a meter. In construction it is a cast-iron case capable of holding 50 lb. of water and a float which simultaneously actuates a pair of valves connected with a walking beam so that one of them is open at all times. When the outlet valve is shut and the inlet valve open, the trap continues to fill until 50 lb. of water have been received. At this point the float actuates the mechanism which instantly reverses the position of valves and the trap operates until 50 lb. have been discharged, when the float again causes the mechanism to put the valves in original position for refilling. Each discharge of 50 lb. of water is recorded on dial placed on outside of meter and this dial reads directly in pounds of water, eliminating the necessity of conversion factors.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by November 1, 1908, for publication in a subsequent number of the JOURNAL.]

POINT BEKA CREVASSE, MISSISSIPPI RIVER RIGHT BANK, PARISH OF ORLEANS, LOUISIANA.

By Frank M. Kerr, Member of the Louisiana Engineering Society.

[Read before the Society July 13, 1908.]

The crevasse of which this paper treats occurred in the public levee on the Point Beka Plantation, in the Parish of Orleans, on the west bank of the Mississippi River, about 15 miles, by river, below Algiers, opposite New Orleans. As the name, Point Beka, indicates, the river bank or batture along there is what is termed and known as a "making bank," and the public levee, located there many years ago, is some distance away from the river bank, as much as 1 000 ft., the batture, or foreshore, intervening between it and the river, being densely overgrown with timber, brush, vines, etc.

The avenues of approach to and communication with the locality where the crevasse occurred were by way of the usual dirt road paralleling the public levee from Algiers down, and by the river. The first, owing to high water, sipage, etc., was slow, uninviting and impracticable for anything like active or extensive approach, and the second, owing to the distance of the levee from the river bank, the timber, etc., afforded no near landing places. No railroads, no telegraph, no telephone, were available. The river was, therefore, as a matter of course, promptly adopted as the most direct means of reaching the locality, one landing being established a mile and a quarter above and another a half a mile below the crevasse.

The levee line at Point Beka, averaging about 10 ft. in height, presented, on the surface, a very good appearance, grade well above the high waters of the past, crown some 8 ft. wide, flat slopes averaging 3 and 3 to 1, and all clean and well turfed. It was, however, known to be infested with crayfish and had become so honeycombed by them as to require constant attention during high water, and the construction from time to time of numerous "mud-boxes," tentative cofferdams, as it were, to surround the apparently worse places in the line. It was at one of these "mud-boxes," constructed a year or so before, that the breach occurred. The crayfish had, no doubt, so chambered the embankment there as to leave it a mere shell, which, notwith-

standing the reinforcement attempted by means of the "mud-box," succumbed to the severe pressure of the high stage of water against it.

The break occurred at about seven o'clock, Saturday, June 6, during the period of high water in the Mississippi River this season, developing a width of about 30 ft. by two o'clock that evening. Steps were the same day promptly taken by the Orleans Levee Board.— the local organization charged with the care, preservation and maintenance of the levees in the Orleans Levee District — to close the break, but without success, the work attempted failing on the night of the 9th, and further efforts were suspended pending developments. After a couple of days' consideration, however, it was determined to make another attempt to close the crevasse, and preparations were at once made to do so.

By Friday, June 12, organization was effected, and the filling of sacks and the construction of the cribbing begun. This was carried on uninterruptedly, day and night, in spite of much inclement weather, and the cribbing completed by noon on the 20th. Sacking followed within an hour after the completion of the cribbing, and by six o'clock the next morning, Sunday, the 21st, the flow through the crevasse, with the exception of the usual leakage common to such work, was checked, the territory back of the breach becoming rapidly relieved of overflow.

The construction of the "mud-box" around the cribbing, with further sacking and the trimming up of the cribs to provide for shrinkage and settling, came next, and the work in its entirety was satisfactorily completed by Thursday, the 25th, no cause for further anxiety for the locality having since developed.

By the time the second attempt to close the crevasse had gotten well under way, the width of the breach in the levee had grown to about 100 ft., beyond which it increased but little up to the closure, being then found, by measurement, to be 109 ft. wide, the upper and lower wings of the work constructed during the first attempt to close the crevasse remaining intact and acting as permeable spurs or dikes, proving an invaluable aid in protecting the exposed ends of the levee from further material loss.

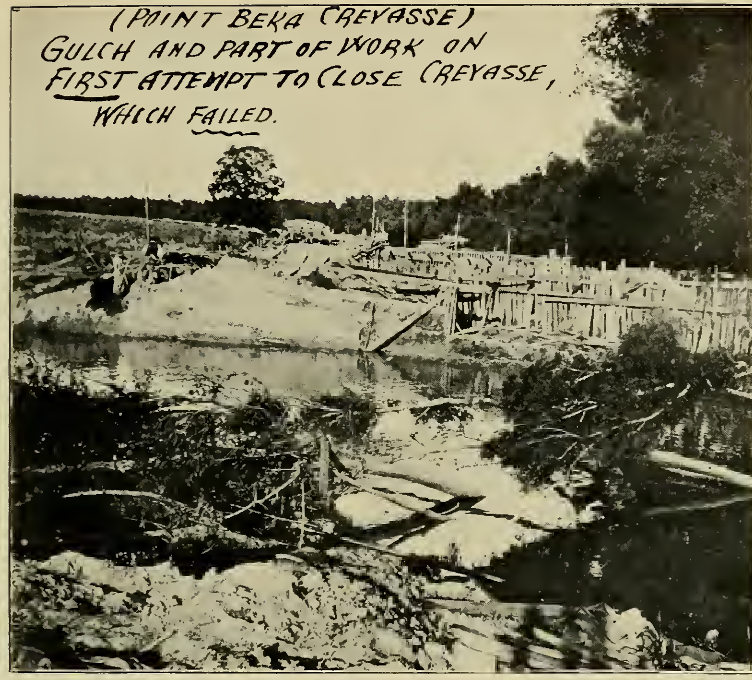
The channel or "gulch" through the levee averaged some 50 ft. in width and from 18 to 20 ft. in depth below the natural surface of the ground, and extended from a point about 150 ft. on the river side of the levee to a point some 250 ft. on the land side of the levee. There was neither time nor opportunity nor

Along Main Line of Levee, below Crevasse.

THROUGH THE "CHANNEL," OR "GULCH."

"BABY," OR "DOLLY," AT WORK ON CRIBBING.

NEW WORK ON SECOND LINE, THROUGH TIMBER.


(POINT BEKA CREVASSE)
GULCH AND PART OF WORK ON
FIRST ATTEMPT TO CLOSE CREVASSE,
WHICH FAILED.


POINT BEKA CREVASSE.
REAR ELEVATION OF SECTION OF CRIBBING ETC.
(SECOND LINE), NEXT TO LEVEE.

Part of Cribbing, Etc., in the Timber.

means of accurately ascertaining the velocity of the current through the break, but it could not have been less than ten miles an hour, and, at times, was possibly as much as fifteen.

Not a single method was adopted or used in closing this crevasse not already fully known to any one familiar with such work. Nothing new whatsoever. *Just* the same old " git-up-and-git " tactics followed by the " Old Timers " of Bayou Lafourche and the Lower Coast in days gone by, only on a much larger and more elaborate scale, and conducted with more system, formulation and deliberation than was possible or needed in olden times.

The most important initial factor in the work of controlling crevasses is an intimate knowledge and appreciation of what one is " up against " ; next, organization, dispatch and attention to detail. Time is " king," and must be so recognized — no flurry, or hurry or scurry. Not one moment, however, must be lost in being up and doing, while all question of dollars and cents, that is, cost, must be lost sight of.

Organization means the preparation of bills of material, establishing lines of transportation; depots for receiving materials and supplies; housing and feeding employees and laborers, for day and night shifts; securing a proper division of labor, both superior and inferior, by the establishment of departments, including the selection of proper persons to fill positions, whether superior or inferior, and last, though not least, the direction over all by one general supervisor, whose will and word shall be law.

At Point Beka the greatest drawback was its inaccessibility and the absence of any direct and prompt means of communication with the point of supply, New Orleans. As already explained, the nearest means of direct approach was by river, at landings one and one-quarter and one-half miles, respectively, above and below the breach. From these landings everybody engaged upon the work had to pass to and fro, and everything needed upon the work had to be transported either by hand, by wheelbarrows, trucks and sleds drawn by mules, along the narrow ribbon of earth afforded by the levee, or by small barges or pontoons cordelled along the side of it, the country on both sides of the levee being submerged, and the crown of the levee being but little more than about three feet above the surface of the water.

Large barges, as depots for materials and supplies, and quarter boats for housing and feeding the employees and laborers,

were located at the landings above described, with headquarters in a hastily constructed " shack," as near the breach as safe and practicable. An attempt was at first made to establish a telephone station at " headquarters," but it was found to be an impracticable undertaking, there being no circuit on that side of the river nearer than six miles. However, a station was later secured at a point on the opposite side of the river, which, in connection with a dispatch boat (gasoline launch), did excellent service.

Perhaps the next thing of interest would be some little insight into the bills of materials, transportation and supplies, etc., called for.

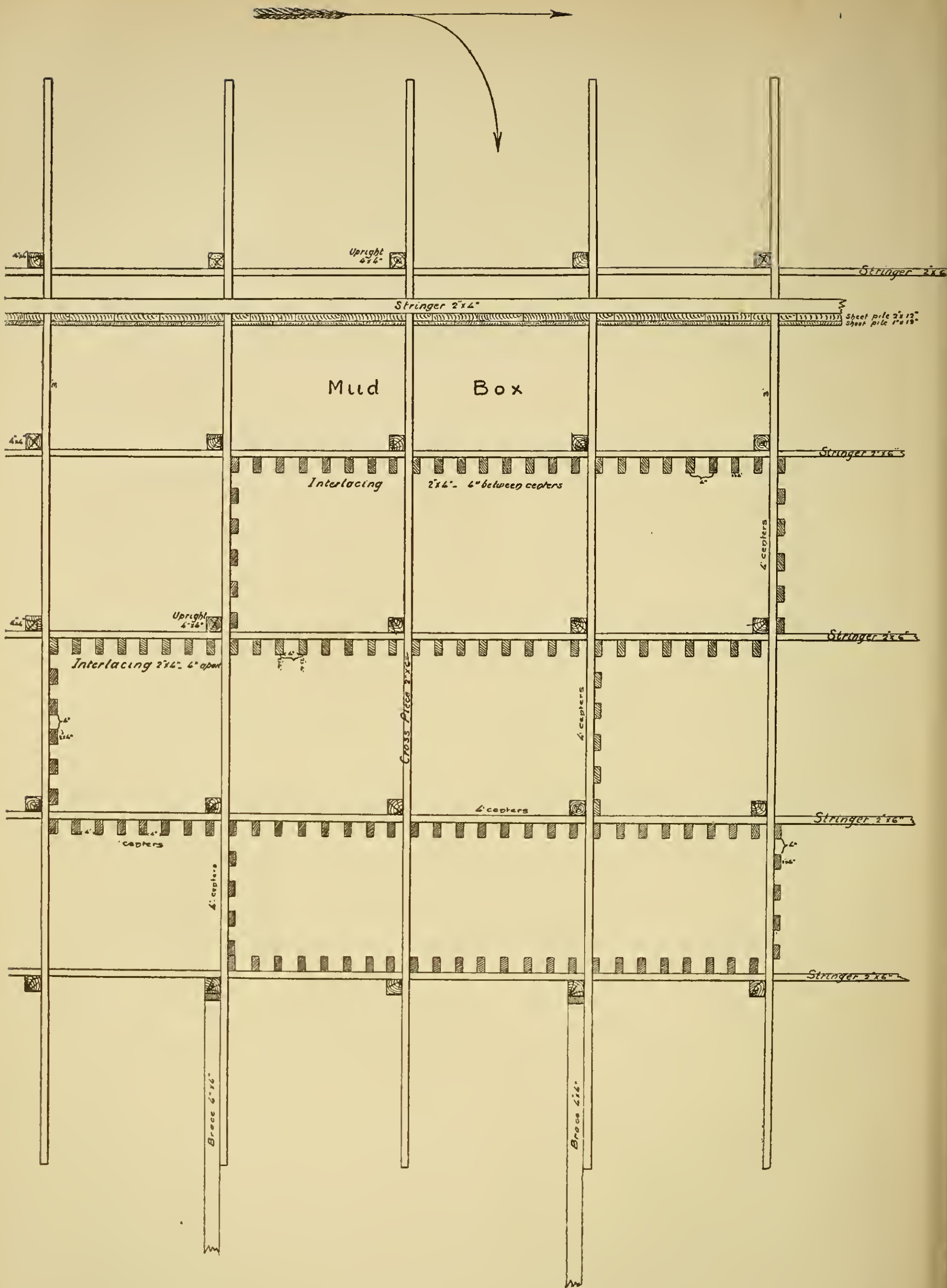
Well, here was the first order, followed, from day to day, by many others: *Materials:* 215 000 feet B. M. of lumber; 65 000 sacks, with twine and needles to suit; 50 kegs of wire nails, 20d. 40d. and 60d.; 50 bales of rice straw; 4 coils of $\frac{5}{8}$ in. manila rope; 4 large tarpaulins; wheelbarrows, long and short handle spades, hand mauls, top mauls, axes, hatchets, adzes, hand and cross cut saws, trucks, gasoline torch lamps, lanterns, locomotive head lights, pine knots, insurance oil, gasoline oil, etc., all " galore." *Transportation:* 2 large harbor tug boats, 4 large model deck barges, 2 large covered barges, 20 small barges or scows, 10 skiffs and 4 large model quarter boats. *Assistants and labor:* one general superintendent of labor and supplies, with full authority to make requisitions for everything necessary for the general comfort and feeding of the whole force on the ground, with as many foremen, stewards, cooks, waiters, scullions, etc., as he deemed necessary; two assistant engineers; four superintendents of sacks; four superintendents of lumber orders; four bridge foremen, with full complement of men for crew for each; and last, but not least, a daily average of about five hundred laborers.

And now about *Construction.* Though very simple, it is difficult to describe it. The sketches and photographs may help out.

The object sought is to subdue the energy of flow by degrees, but with sufficient dispatch to subject the bottom upon which the structure rests to as little scour as possible. Therefore after selecting the route to be followed by the structure, a skeleton, consisting of uprights, stringers and cross pieces, is built around the breach along the route selected, preferably on the river side of the levee in which the breach exists. The uprights are spaced longitudinally and transversely, as conditions and circumstances demand. In the structure at Point Beka, the uprights, 4 in. by 4 in., were spaced 4 ft. from centers each way, the stringers and

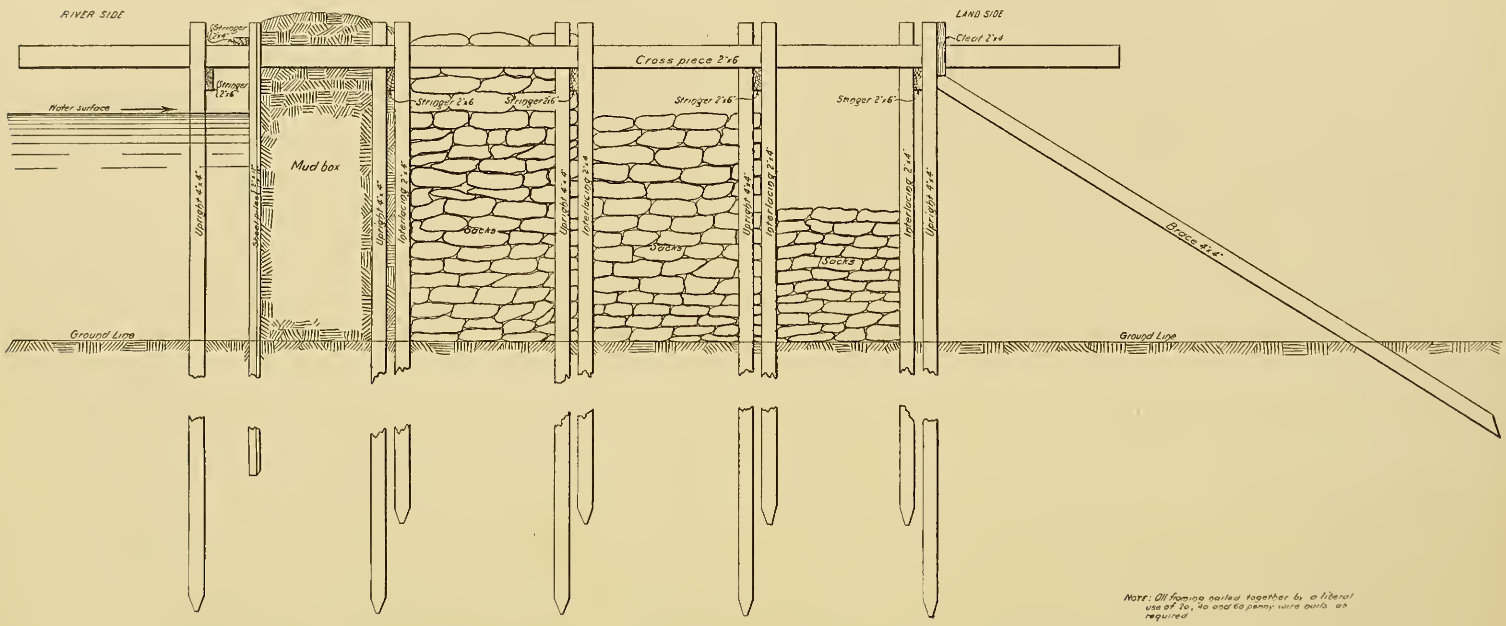
cross pieces being composed of 2 in. by 6 in. Next, the spaces, formed by the rows of uprights, stringers and cross pieces, are interlaced longitudinally and transversely, as shown on plan, with other uprights, usually, as at Point Beka, 2 in. by 4 in., spaced 6 in. between centers longitudinally, and 8 in. between centers transversely, with the narrower face always against the current. The result is a series of cribs breaking joints, as it were, as shown on plan, about 4 ft. wide and 12 ft. long. At Point Beka, the 4 in. by 4 in. uprights were given a penetration of about 8 ft., driven to an elevation about 3 ft. above the water, and the longitudinal stringers were nailed to the uprights, at an elevation of about 2 ft. above the water, with the cross pieces, also nailed to the uprights, immediately above and resting on the longitudinal stringers. The 2 in. by 4 in. interlacing was given about the same penetration as the 4 in. by 4 in. uprights, and driven down as nearly flush with the longitudinal stringers and cross pieces as practicable. All the piling — uprights — was driven by hand pile-drivers, more commonly known as "babies or dollies." (See photograph.) Bracing the structure then followed. At Point Beka this was very simple. A piece of 4 in. by 4 in. driven into the ground on the land side, on a slope of about 3 to 1, fitted and nailed to every other 4 in. by 4 in., with a stiff cleat fitted and nailed above the head of the brace. This quickly adjusted form of bracing is preferable to any kind of interior bracing, as it in no way interferes with the sacking or with the settling of the sacks, as the other is more than apt to do.

As soon as the interlacing is completed, sacking is begun, a sufficient number of sacks to insure no interruption in the progress of the work having in advance been filled and securely closed and sewed up. Right here it should be stated that the sack should not be filled too full, only about three quarters full, to allow for pliability, to induce adjustment to inequalities; and that the thorough tying and sewing of the sacks is very essential. The sacks, of course, were filled with earth borrowed from the levee above and below the breach. The cribs along the land side of the structures are the first to be sacked from end to end. Sacks sufficient only to thoroughly floor these cribs, and to correct any differences of level in the floor, are at first lowered into them. Then the next row of cribs is sacked, from end to end of structure, to a somewhat higher elevation than the first, and the next still higher, until the last row of cribs facing the river side of the structure is reached, in which row of cribs the sacks are brought up to an elevation just above the surface of the water



Plan of Part of Cribbing.

Cross-Section of Structure.



in the river. Then more sacking continues, uninterruptedly, of course, until a safe elevation in each row of cribs is reached, and the flow through the structure is checked, or rather coaxed into submission. Just here a word of explanation about that item of "hay" in the first bill of material mentioned. This is gathered from the bales, by the handful — just the handful — and scattered in the cribs, among the sacks, during the process of sacking, to be borne by the current into the small interstices occasionally occurring between the sacks, and thus temporarily assist in checking small leakages, as may be readily understood.

By the way, too, sacking does not consist of dumping sacks pell-mell, helter-skelter into the water. Not by any means. Each sack should be taken from the shoulder of its carrier and lowered into the water by men assigned to that duty. At Point Beka, a large proportion of the sacks were filled at considerable distances from the cribbing and had to be handled several times before reaching it, — by hand, by wheelbarrows, by sleds drawn by mules and by pontoons cordelled along the levee.

After sacking, the construction of the "mud-box" along the river side of the structure follows. This is usually, as at Point Beka, made about 3 ft. wide, the river wall of the box consisting of a double row of sheeting piling, 2 in. by 12 in., and 1 in. by 12 in., breaking joints, — the 1 in. by 12 in. on the inner side of the wall, — driven to an elevation about 2 ft. above the water in the river, about 3 ft. into the ground, and nailed to a horizontal stringer, 2 in. by 4 in., secured to the cross pieces and uprights, with the cribbing and sacks constituting the land side wall of the box. The box is finally filled up with earth, effectually cutting off all flow, that is, when the structure proves successful.

The form of the structure [illegible] the breach was in the shape of a succession of tangents inscribed upon a semicircle having a radius of about 200 ft. The route followed was selected after a careful survey of the batture or foreshore and the depth of water over it, and determined by depth of water, character of bottom and clearings in the timber and brush, — the shallower the water and the clearer the course, the better, as a matter of course. The length of the structure was 741 ft.

Very few mishaps in construction occurred at Beka. Shortly after the work was first completed, some half a dozen "boils" developed on the land side of the structure, two of which, where it crossed old borrow pits, proving for a while quite serious. All were, however, finally successfully treated, and the work as a whole declared, by all who saw it, to present a thoroughly sub-

stantial and workmanlike appearance. The total cost of the work performed, under the direction of the writer, was about $37 500. The damage to property and crops resulting from the crevasse was purely local, probably not exceeding $50 000 actual value. Had the crevasse not been so promptly closed, however, it would beyond doubt have widened and deepened to such an extent as to affect a very large extent of country and to cause damages reaching into the hundred thousands.

Finally, it might be well to say that the gage at New Orleans, at the time of the closure of the crevasse, recorded a stage of 19.8 ft., that is, within a half a foot as high as the highest water of record there. At the same time, too, the water was still rising, reaching the maximum stage for this year, 1908, 20 ft., the day after the closure of the crevasse, or only 0.3 ft. lower than the highest water of previous record. With this stage, the head of water against the completed work stood from 6 to 9 ft.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by November 1, 1908, for publication in a subsequent number of the JOURNAL.]

A SHORT ACCOUNT OF THE LAWRENCE FILTER BEDS.

By Arthur D. Marble, Member of the Boston Society of Civil Engineers.

[Read before the Sanitary Section, June 3, 1908.]

In the late fall of 1875 the water works of Lawrence, which had been in process of construction for two years, were completed and water was turned into the distributing system of the city. Some purification at seasons of high water, when the river carries a large amount of earthy matter, was attempted by the construction of an 8-ft. filter gallery running parallel with the river bank for 300 ft. easterly from the pumping station, but this soon silted up on the river side, and the water was drawn without any actual preliminary purification directly from the river.

Many of our citizens now wonder that the river water was ever selected for our public water supply. The quantity, however, was unfailing, the water soft and good for all sorts of mechanical purposes, and thirty-five years ago scientists considered it all right also for the human mechanism. In 1872 the engineer who reported on the proposed water works said: "One of the most remarkable qualities of running water is that of self-purification," and that "all traces of noxious matter thrown into a running stream have disappeared in the course of a few miles." One chemist who made an analysis of the river water found that opposite the present site of the pumping station it "retained no serious trace of the impurities received at Lowell and above." Professor Appleton said of samples of the river water submitted to him for examination, that the chemical analysis showed "them to be well suited both for domestic and general manufacturing purposes," and the conclusion was that "no city has a better or purer supply of water than has Lawrence." At that time the germ theory of disease played no part in the selection of a public water supply, and we now know that these conclusions regarding the purity of the water were wrong.

It was more than ten years after the completion of the works before any serious apprehension was felt concerning the purity of the water. The report of the Water Board for the year 1888 speaks of the investigations of the State Board of Health which had been going on for more than a year, and states that "their

very able report shows that the water supply of Lawrence ranks favorably with other works of the state." For nearly twenty years we continued to drink the raw river water, loaded with the impurities from the drainage of the large cities above us, and every time that Lowell had an epidemic of typhoid fever, Lawrence followed with a similar epidemic shortly after; and in spite of all the favorable reports to the contrary, I think the bulk of the people have never felt that the river water was, or is now, even after purification, really fit to drink.

In 1891, the State Board of Health, which had been experimenting for a few years with different systems of filtration, had not then recommended any particular one, and the Water Board reported to the city council in favor of installing mechanical filters, at a cost of from fifty to sixty thousand dollars. The report was accepted without reading, and nothing was done. The following year the Water Board determined to do all in its power to satisfy the public demand for pure water by the introduction of some form of filtration. They again sought for advice from the State Board of Health, and on June 5, 1902, that board reported in favor of the uncovered filter bed, which was begun in the early fall of that year and put in commission in September of the following year. This bed I shall refer to in the course of this paper as the "old," in distinction from the "new," which was built in 1906–7. The scheme was the result of experiments made for several years at the State Board of Health Experimental Station in this city, under the direction of Mr. Hiram F. Mills, member of that board, and chief engineer of the Essex Company. Mr. Mills designed the bed, acted as consulting engineer throughout its entire construction, and visited the work nearly every day, all without a cent of expense to the city; and the excellence of our present supply is due to his wisdom and his faith in the certainty of the good results which would follow the installation of his plan.

When first completed the entire surface was undivided, a little unbroken lake, 2.5 acres in area. It was early felt that with our severe winters smaller areas could be cleaned with less peril to the efficiency of the bed, so in 1902 two cross walls of concrete were built, dividing the original bed into three very nearly equal areas. It is now possible to drain and clean one section without exposing the surface of the other two sections to the danger of freezing, and at the same time allow of the filtration of water to nearly two thirds the full capacity of the bed.

From the first the bacterial efficiency of the bed has been

exceedingly gratifying, and its continued and undiminishing efficiency is shown from the fact that while the bacteria have increased in numbers in the river water, there has been no increase in the filtered water. The record of the deaths from typhoid fever is perhaps more interesting than any other feature of the results of the filtration of the Merrimac River water. In the six years immediately preceding the construction of the filter there averaged 43 cases of typhoid fever, with 12 deaths per 10 000 population. In the six years after the construction of the filter the average cases were 15, with 2.6 deaths, a reduction of 65 per cent. in the number of cases and 78 per cent. in the number of deaths. In the first five months of 1892 the typhoid death-rate was seven times that of Boston. It is now about the same as that for the whole state.

As I have already stated, the old bed is about 2.5 acres in area. Both the surface and the bottom of the bed consist of a series of ridges and hollows, spaced about 30 ft. apart. The underdrains are located in the hollows of the bottom, one in each, covered with gravel 1 ft. in depth, graded in five sizes, from 2 in. to 3-16 in. in diameter, the coarsest immediately around the pipe. The gravel is covered with a thin layer of coarse sand, on which the filter sand is placed 5 ft. deep in the sections over the underdrains and 3 ft. deep midway between the underdrains. The section of the sand 10 ft. wide in the center between the underdrains was coarser than the section of sand 20 ft. wide immediately adjacent to and over the underdrains. Through these different grades of sand, and the varying distances, it was expected that the water would travel with about the same degree of purification from all parts of the bed to the underdrains.

The people of Lawrence as a whole have never questioned the wisdom of the construction of the old bed if the use of river water is to be continued. They have, however, questioned the wisdom of being satisfied to always draw from the river, and to quite an extent still question it. Many think that because Lowell was lucky enough to get an abundant quantity of water from driven wells, and abandoned the use of the river water entirely, Lawrence could do the same. They imagine that the ground almost anywhere is full nearly to the brim with water, and all we have to do is to drive wells, and behold, 76 000 people are supplied abundantly! To those who know and realize where the ground water comes from, the problem is far from such a simple affair. Engineers note the location of the ridges of hills surrounding a pond area, and a pretty safe estimate of the amount that pond

will yield can be made. So in every case in the immediate vicinity of Lawrence, where the people were positive a sufficient quantity of water could be secured, the bounds from beyond which the water could not be expected to pass were near at hand, and we felt quite sure our efforts would be as void of satisfactory results as it would be to attempt to supply a family continuously from an ordinary wash basin.

By 1901 the old bed was taxed to its utmost capacity in the winter season, and the need of greater filtering area became startlingly apparent. With the talk of more water, the demands for another source were renewed with vigor. In 1905 we spent nearly the entire season hunting for ground water in localities near enough to the pumping station and reservoir to make both useful in its distribution. And although we spent about $5 800 in this jack-o'-lantern chase, nearly brought the city to a water famine, and although the contractor engaged to drive the wells, who hoped to reap a golden harvest if water in satisfactory quantity and quality were found, pronounced the search useless, I fear many of the citizens of Lawrence think it was a put-up job not to find water, and that driven-well water is here in abundance if we will only make a hopeful hunt for it. I am sure that those engaged in the work at that time would have been only too glad to have secured in this way an adequate or even a limited supplementary supply. Most of the water found contained so much carbonic acid that it would have been unsafe to use through our lead services, and it was consequently condemned by the State Board of Health. This conditon also was unfortunate, for it led many of our citizens to feel that the State Board were bound to continue their experiment (as they considered it) of the use on a large scale of sand-filtered water in a good-sized city, and in that way our filter bed was but a branch of the state experimental station, for which Lawrence was paying the bills.

During the time the city was doing its best to find driven-well water, the Committee on Water Supply of the legislature were striving to make Lawrence undertake something that would surely increase its water supply. But we continued our experiments with driven wells, and another winter came, luckily milder than some previous ones, so conditions at the reservoir did not become as critical as in some previous winters. At one time there was but two days' supply of water in the reservoir, and those in charge of the water department could hardly sleep, fearing that a great conflagration or some other dire calamity would reduce even that quantity to nothing, with the possibility of its

becoming necessary to open the gates direct from the river to the pump well. The people thought that these conditions at the reservoir were purposely aggravated or even manufactured entirely by the Water Board in order to force the construction of a new bed upon the city. They apparently believed that the superintendent, Mr. Collins, was fond of much self-torture, and almost of suicide.

Early in 1906 the city council authorized the loan of $70 000 for the construction of an additional filter bed from plans prepared by Mr. Morris Knowles, of Pittsburg, Pa., a native of Lawrence, at one time member of the Lawrence Water Board, and then, as now, the chief engineer in charge of the construction of the great filtration works of Pittsburg. The order passed with little or no opposition. They had settled down to the conviction that the river water must be used for the present, at least, and that more water must be immediately provided. Indeed, a water famine would have come long ago had it not been for our exceedingly low consumption of only a little over 40 gal. per capita, resulting from the metering of nearly 90 per cent. of the services. A contract for the construction of the filter was let in May to M. O'Mahoney, for more than thirty years a citizen of Lawrence, and for all that time extensively engaged in general contracting work. The estimated total cost of the items of construction contained in the contract was about $47 500. There were some additions made to the original plan during the progress of the work, and the actual total cost of the contract as it stood when accepted by the city was about $49 500. The total cost of the bed complete, including everything, to January 1, 1908, was about $54 300. Since then the water department has done considerable work in grading and finishing the grounds and the surroundings, which should properly be added to the above figures of cost. Although work was begun at the beginning of the summer of 1906 there were some delays which carried its completion into the year 1907, necessitating the purchase of water from Andover and North Andover in the winter of 1906–7, at a cost to the city for the water and the pipe connections of about $10 000.

In April, 1907, when about one third of the roof was in place, a portion of it, having an area of nearly 6 000 sq. ft., which had been constructed in the previous December, fell, destroying most of the roof centering, with about 172 cu. yd. of concrete. The cause of this failure was treated at considerable length in a paper by Mr. Thompson before the New England Water Works

Association in February last, and will soon appear in print in the transactions of that association.* The accident happened while the carpenters were removing the centering. Luckily no one was injured.

The new bed covers an area of about three quarters of an acre. A part of this area was taken out of the river, and a part from the hillside adjoining. The river embankment was first made, the water enclosed thereby being then pumped out. A line of 4-in. sheet piling was driven through the length of this embankment. There were about 35 000 cu. yd. of excavation, costing $11 550. The bed is 21 bays long and 7 wide, the span of the groined arches being 15 ft. between centers of the piers. Manholes in the roof furnish access to the bed, as well as light and ventilation. Large doors at an entrance in the easterly end also admit of access to the bed. The arches at the crown have a depth of 6 in., except under the sand court, where the crown is 9 in. thick, and level on top. The roof under the sand court is also reinforced with twisted steel rods $\frac{3}{4}$ in. in diameter, running both ways, and spaced 9 in. apart. The side walls are 4 and 5 ft. high, from which spring barrel arches to meet the elliptical arches of the roof. These elliptical arches have a rise of 2 ft. 9 in., are generally 6 in. thick at the top, as before stated, and 21 in. thick over the piers. This latter thickness is really much greater, as it was found impossible to prevent the concrete running down into the depression over the piers. The floor consists of inverted arches groined in a manner similar to those of the roof, is 14 in. thick under the piers, and 6 in. in the center between the piers. The piers are 22 in. square, battering below the sand level to 30 in. square at the base.

On the floor is built the main collector, 18 in. by 30 in. in size. It runs in a westerly direction through the entire length of the bed. The walls of the collector were built of concrete in place, and the top covered with slabs of plain concrete 6 in. thick, made elsewhere on the work, and put in place after hardening. Connected with this collector are the lateral drains, running each way from it to within 6 ft. of the sidewalls, in the depression of every bay. These drains consist of half 12-in. pipes, and of 6-in. pipes. On these pipes is placed the gravel, graded in size from a diameter of 3 in. to pea, the coarsest around the pipes, covering the entire bottom of the bed to a depth of 1 ft.

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* See *Journal New England Water Works Association*, Vol. XXII, p. 237, June, 1908.

Above the gravel is the filtering sand 4.5 ft. deep, having an average effective size of from 0.22 to 0.28 of a millimeter. The sand was tested mechanically about five times each day, and continually by a simple test in the bank devised by the State Board of Health when the old filter was constructed, which test determines quickly and in a rough way the fitness of the sand for the work. About two thirds of the sand was washed. The specifications required that not more than 1 per cent. of the sand should be less than 0.13 of a millimeter in diameter. The general run of the bank from which the sand was obtained gave about 4½ per cent. of this size. After washing there still remained from ½ to 1 per cent. About 3 per cent. of the sand was lost in washing, and the sand in the bed shrunk about 4½ per cent. after the water was turned on. None of the sand was left in place after dumping through the manholes, but all was shoveled over. The price bid for the sand was 60 cents per cubic yard. While no accurate data of the actual cost of the sand could be obtained, it is estimated that the sand which did not require washing cost about 56.5 cents in place, and the washed sand about 76.5 cents. After allowing for the shrinkage, which the contractor was not paid for, the above cost became 59 and 80 cents, respectively. The sand in the old bed, carefully selected from veins in the bank, none of which was washed, cost about $1.35 per cubic yard.

The masonry of the new bed was entirely of concrete, mixed in the proportion of 1: 3: 5. The sand and gravel were obtained in part from the excavation for the bed and in part from a bank about 3 200 ft. from the work. The haul to the washers was about 500 ft. shorter. The teams were able to make about nineteen trips a day. Atlas cement was used for the concrete, which stood all the tests called for in the specifications.

The total sand area of the new bed is 31 470 sq. ft., and the cost of the filter bed per sq. ft. was $1.72. The cost of the old bed, which is uncovered and has earth sidewalls and bottom, has been about 87 cents per sq. ft. It is intended to remove the dirty sand from the new bed and replace the cleaned sand by the ejector system through the manholes in the roof and wash and store it on the 90 ft. square concrete court over the middle of the bed.

The water was turned on the new bed in November, 1907, and for two months the water was pumped from the effluent pipe and wasted to the amount of about 1 000 000 gal. per day, until the State Board of Health found the bacterial efficiency

to be such that the water was safe to drink. For two or three months more the amount actually used from the new bed did not exceed 1 000 000 gal. per day. When we began to use the water in January the bacteria numbered something over 100 per cubic centimeter. The number of bacteria in the river varies, but now they number about 4 000 per cubic centimeter. When we first began to pump in November, the effluent from the filter contained more bacteria than the river water, which then numbered about 13 000. The filter was not then ripe for purification work and to the bacteria of the river were added those from the sand.

The bed is supposed to yield a minimum of 2 000 000 gal. per day, which can be increased in time of favorable river conditions to 3 000 000 gal. or more. The estimated available yield from the old bed is 5 000 000 gal., which amount can be increased in favorable times. Mr. Collins, the superintendent of the water works, has in summer time, with a clean bed, got over 6 000 000 gal. from it.

As before stated, Mr. Knowles prepared the plans for the new structure. The engineering department of this city superintended the construction, Mr. Priestman, first assistant in the office, being located almost continuously on the work from beginning to finish. It might be well to state that the engineering department during the past winter has prepared plans for the reconstruction in similar lines of the easterly end of the old filter. The area of this construction will be slightly greater than the new bed just completed. These plans have been formally approved by the State Board of Health, and a contract may be let for its construction another year.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by November 1, 1908, for publication in a subsequent number of the JOURNAL.]

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MODERN PLANTS FOR BUILDING STEEL CARS.

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[Read before the Society May 15, 1908.]

THE building of steel cars began about ten years ago. From the knowledge I have on the subject, I believe the first work of any consequence was done by the Pressed Steel Car Company, of Pittsburgh. Mr. Chas. Shoen began first to make pressed steel parts, such as stake-pockets, car stakes and corner irons, finally making pressed sills, bolsters, and eventually the entire steel underframe for box cars and an all-steel hopper coal car. These first steel cars were known technically as pressed steel cars because of the fact that many of the parts were pressed into shape. At the present stage of the business many of the steel cars built have very few pressed parts, however. The problem before us to-night is to build a plant which will manufacture cars made either from pressed-up shapes or the regular structural shapes obtainable on the market.

This problem is one that includes a wide range of engineering work. A steel car plant is a shop handling a specific form of structural work. As most of you know, the steel car consists mainly of structural shapes and sheets with a small amount of malleable and steel castings and forgings. In addition to this are the trucks, such as are in every steel or wooden car. The regular steel car of 100 000 lb. capacity weighs from 40 000 to 45 000 lb. In designing a plant to turn out fifty steel cars per day, we must handle approximately 1 100 tons of material each day.

The operations this material goes through may be summed

up as follows: Shearing, punching, pressing, assembling and riveting. To do this rapidly and economically we must lay out this plant so that the material progresses steadily forward from the time it enters as raw material at one end until it emerges as the finished car at the other. We will not discuss the building of the trucks, as that is usually done in another shop. The material we have to handle consists mainly of channels, angles and plates. In addition to this we must handle the draw-bars, bolsters, brake rigging and some smaller parts which go to make up the car.

After we have selected the necessary machine tools for performing the operations named, we must next arrange them in the building so that we shall be able to fabricate this material with the least amount of handling, leaving the necessary room between the machines for storing the material being worked without making an unnecessarily large and expensive building, as an excessive amount of space not only means expense of the building and ground, but increases the distance over which much of this material must be carried.

We can probably get a better idea of this matter if we study the arrangement of some of the existing plants which are doing this work. One of the earlier plants was the Pressed Steel Car Plant at McKees Rocks, near Pittsburgh. Although I have been in this plant, I have forgotten the exact dimensions and layout of this building, but as I remember it the plant consisted of two large parallel bays with bays running off at one side, in which the cars were erected. One of the later shops was the Detroit plant of the American Car and Foundry Company. This plant originally consisted of two bays 92 ft. by 780 ft.; 360 ft. have since been added to the eastern span known as the erecting shop. The plant of the American Car and Foundry Company at Berwick, Penn., and also the one at St. Louis, are practically the same size as the one in Detroit; they, however, have more room in their main shop for carbuilding, as they build the trucks in a separate building, known as the truck shop, while in Detroit the truck shop is inside of the main building. A still later building by the Standard Steel Car Company, at Hammond, Ind., consists of two spans, 80 ft. by 1 612 ft. in length.

The American Car and Foundry Company have sixteen different plants for building cars; six of these are designed for the building of steel cars. We have some views to present to-night which were taken of their Detroit and Berwick shops; as these shops are very similar, we will give a brief description first of the Detroit plant. The principal tools used are as follows:

Shears.

Four heavy shears, capable of shearing a plate 10 ft. wide and 1 in. thick, also a number of smaller shears of various types including a special angle shear on a turntable so that long angles can be cut at any angle without having to swing them around the shop; that is, the shear is turned so that it stands at an angle to the pile of material, thereby economizing shop room and labor.

Punches.

Four multiple punches capable of punching a row of holes entirely across a plate 10 ft. wide at one stroke of the machine, and of sufficient length to take plates of 50 ft. in length. These machines deserve special mention, as they are self-spacing. There are two levers at the side of the machine (where the operator stands) like the reverse lever on a locomotive and about the same size. These levers have graduated arcs, one being graduated for inches and the other for eighths. By simply throwing these levers the machine will space any distance desired up to 7 in.; in other words, if you have a plate across which you want to punch a row of holes every 7 in., and this plate is started in the machine, with the spacing lever set to 7 in., the machine will automatically feed it through, punching a row of holes every 7 in. If instead of 7 in. you want to make it 4½ or any other number, you simply set the lever to read that way. A great deal of the work put through these machines has various spacings on the same sheet. The operator, keeping his schedule before him, will set these levers to the proper spacing without stopping the machine, so that the plate goes forward automatically, first making a space of 4 in., another of 2½ in. or whatever may be wanted. In addition to this the punches are all arranged with gags so that any punch can be instantly thrown out and the holes omitted wherever it is desired. The operator also has a smaller lever in front by which he can instantly gag all the punches if for any reason he wishes to omit one spacing, or if he should possibly notice before the punches go down that he had made a wrong spacing, he could prevent the punches from doing any work. These gags consist of steel blocks about 2 in. thick, above the punches, which are simply withdrawn so that the punch, instead of going through the sheet, slides up into the socket, or rather the punch and socket both slide up into the upper head or ram of the machine. These machines not only have the advantage of saving an immense amount of labor in marking and punching, but will do the work much more accurately than it is possible to

do it by hand. The American Car and Foundry Company are, I believe, the only car manufacturers who use this type of machine. In addition to these multiple self-spacing punches, there are a variety of both small and large punches, such as will be found in any good structural shop. On some of the larger punches a great deal of special work can be done, such as coping flanges on I-beams or cutting the angles or channels to any special shape desired.

Pressing.

The presses in this shop consists of two 1 000-ton presses and two 500 ton. By 1 000 ton, we mean a press which will exert a pressure of 1 000 tons on the work. Many cars have pressed steel sills. These are pressed cold from plates usually ½ in. thick and perhaps 30 in. wide at the center, tapering down to 18 or 20 in. at the end, these plates, of course, being the full length of the car. This work being too long to be done at one impression, the dies are made in three sections and all three sets of dies are placed on the press at once. The plate is pushed into the press and placed so that one third of it is pressed. It is then pushed in farther and the middle section is pressed and is then pushed on for the third impression, each section of the sheet being pressed to its final shape at one stroke so that after the sheet has been passed through the press it is finished so far as the pressing is concerned. The dies for this work are about the heaviest things to be handled in the shop. The traveling cranes, of which we will speak later, are made heavy enough to handle these dies, which are of cast iron, and which have to be changed every time the press starts on a new lot of work. One of the 500-ton presses is what is known as the flanging press. This press has three cylinders, the main plunger remaining stationary while the two auxiliary plungers push down the clamping bar, holding the sheet in place until the main platen comes down and bends it over. In some cars a great many sheets have the edges flanged at 90 degrees or less according to the design of the car. This work is done on this press. The presses used at this plant all have a fixed lower platen while the upper platen descends on the work. In some other plants presses are used where the upper platen remains stationary and the lower one rises. These are perhaps more particularly adapted to small work. On some of the smaller presses I have seen men insert four pieces simultaneously from all four sides of the press, so that four pieces were pressed at once.

Each of these presses has near it a heating furnace, as most

of the work pressed is heated. The heating furnaces at the large presses are 20 by 30 ft. and will take in any part of a car which needs to be heated. These are reverberatory furnaces, and in the Detroit plant they are fired with soft coal, although in some other plants they are heated with oil. In addition to the above machines there are saws for cutting off I-beams or other special shapes.

There is a variety of other equipment which we cannot enumerate in detail, the truck shop having axle lathes, wheel-borers, arch-bar drills, wheel presses, etc., such as are used in any truck shop. The axle lathes in the Detroit shop are especially heavy modern tools, each driven by its own motor, the Bullock multiple voltage system being used, giving six changes of speed. There is a full machine shop equipment for taking care of the tools, including a heavy planer 10 ft. wide, this being necessary for fitting up the dies used in the presses. There are also four machines for making rivets, two bulldozers for bending arch-bars and upsetting and pressing various parts. There are about thirty rivet fires scattered throughout the plant. These furnaces are heated with oil and have an air blast conveyed through an underground tile pipe system, the air being furnished by blowers direct connected to high-speed motors.

We have now gone over in a general way the operations necessary in preparing this material for assembling and riveting. In a steel hopper car of 100 000 lb. capacity there are about 2 400 rivets to be driven. To be exact, on Pennsylvania hoppers recently built at this plant there were 2 434 rivets, on New York Central gondolas 2 449 rivets, and on Southern hoppers 2 340, so that when this plant was building 100 cars a day, as it was for a considerable time last year, it was driving 240 000 rivets per day, the day including a night shift.

To drive this large number of rivets to the best advantage the material is assembled as far as possible in sections, these sections being riveted on machines especially adapted for each particular work; for example, the whole side of a hopper or gondola car is bolted together with erection bolts and hung from a trolley over the top of a deep-gap riveter. These riveters are 10-ft. gap, and in this plant we have nine of them. The Standard Steel Car Company's shop at Hammond has seven 114 in. gap. These riveters have a heavy U-shaped frame with the open side up, and are placed in a pit so that the rivet being driven is about four feet from the floor. The operator who handles the riveter also has within reach two levers whereby he can raise and

lower the work and also cause it to travel endwise. On a large surface like the side of a car, when handled this way, the rivets can be driven very rapidly, from a dozen to twenty rivets being sometimes put in in a minute, depending, of course, upon the accessibility of the work and the rapidity with which the operator can move it. One man shoves in the rivets, another man operates the machine and moves the work, while usually a couple more men are required to steady the work so as to bring the rivets into position rapidly. Not only car sides, but many other parts, are riveted before the work reaches the erection floor; the sills have the lugs and malleable parts all riveted in the machine before the sill goes to the erecting floor. Bolsters and many other parts of the car are riveted complete in the same manner, much of the smaller work being done on small hydraulic riveters. When the work finally comes to the erecting floor a great many rivets in every car must necessarily be driven with a pneumatic riveter, held in the hand, known in shop parlance as a "Gun." These machines such as you have all seen used in the field on structural work do this work very rapidly, but when a hundred of them are going at once inside a building conversation is necessarily prohibited; even a megaphone would be useless. A fixed hydraulic or pneumatic riveter works so much more rapidly and quietly than the gun that, so far as possible, all work is done on the fixed machines. Some work which cannot be done on the fixed machines is done on the erecting floor with a portable riveter, which carries an air cylinder and heads the rivet at one stroke the same as the fixed machine; the best type has the cylinder attached to a toggle joist so that a small cylinder can exert the necessary pressure. In a great many places, especially in assembling the underframe, these machines can be used efficiently. A portable hydraulic riveter has been tried, but it requires such complicated connections to take care of the supply and return water that it is not practical.

Erection.

We now come to the erection proper; there are two systems used. In some shops a car is erected on a pair of horses and each car is completed in its particular place, that is, one set of men builds the car complete in a fixed place, there being a number of these sets of men according to the size of the shop. The other system might be called the progressive system, whereby the first gang performs a certain operation; the car is then passed along on its own trucks to the next gang and from it to another, in all

about eight or ten gangs being used before the car is completed. This later process is the one used in the Detroit plant and has been very satisfactory. The system as carried on here consists of placing the trucks on the erection floor and at once beginning the erection of the car on these trucks, the center sill being dropped on first, then the cross pieces or body bolsters, then the side sills and so on. The first gang of men simply gets far enough to put on the side sills, usually throwing a short plank across each truck while this is being done. I might also mention that the trucks are shoved closer together than their normal position so that the drawheads can be put in and the men can also get at the rivets over the trucks. This car is then pushed along to the other gangs who do the riveting on the underframe, put in the drawheads and assemble the car through its various stages, the underframe being riveted up before the upper part of the car is erected upon it. The same progressive system is used in the Berwick shops. The Pressed Steel Car Company in Pittsburgh use the other system, building each car on a pair of horses. The Standard Steel Car Company also build their cars on horses. At the Berwick shops this plan was tried for a time, but changed over to the progressive system. There are various points for and against each system, and it might after all be largely a matter of education and training as it is with many other things we have to do with. There are a number of advantages in favor of the progressive; one is that for the same output very much less floor space and shop building are necessary. The material of each particular kind is placed in the exact spot where it will be used; that is, the center sills, for example, would be placed at the first station; each station has only a certain class of material to look after. The men in that gang have only one particular operation to perform on each car and they become very expert in performing that operation. With a few good men in each gang to take the lead, the gangs can be filled in with common help until they are properly evened up. If not properly evened up, the output is undoubtedly limited by the weakest link in the chain. This is the one objection offered to this system, but with the proper supervision I believe that it is not a serious one. With the fixed system all the material for a car must be delivered at each of the stations. More room is required to get all around the car as well as to pile up all the different parts required. One point of advantage in this system is, that if the work is done on a piece work or premium plan, each car can be erected for a fixed price; in other words, the piece-work system is possibly more adaptable where

the cars are built on horses than it is where the progressive system is used. Personally I believe that the progressive is the best, but this may be partly because I have been more closely in touch with it.

We have now followed the material until it has reached the assembled car, and by the time it reaches the end of the shop it is completed ready for painting. Most of these cars receive three coats of paint, but the work is done very rapidly and in good weather can be done out of doors. The Detroit plant, however, has two large paint shops capable of doing this work under cover if necessary. In the winter these shops are kept heated to a fairly high temperature in order to dry the paint as rapidly as possible. You can readily see that in a shop like the Detroit plant, where a few months ago they were turning out a hundred cars per day, to store these cars until three coats of paint were dry requires a very large amount of space. Supposing the cars are painted in three days, we must have room for three hundred cars, or nearly three miles of track.

We have so far not taken up the means of transporting the material around the shop. The eastern span of the Detroit plant carries three traveling cranes, 92 ft. span, 10 tons capacity. These cranes all run on the same track, the crane rail being 40 ft. above the ground. In the western span are two more cranes of the same type and capacity. These cranes travel at a high speed, making 480 ft. per minute, and when the shop is running to its full capacity they are kept extremely busy. As the cranes in each span run on the same track, they cannot, of course, pass each other, and each crane must do the work in its own section or the other cranes must get out of the way. Fortunately the work progresses so in these shops that the cranes seldom have to travel more than one half or one third of the length of the building. We might state here that this entire shop is free from any belting, piping or wires which would obstruct the travel of these cranes.

Each one of the large machines has its own motor attached to it. The only shafting and belting in the building are placed along the side and center columns, and all the piping and wiring are carried in conduits and trenches beneath the floor so that there is nothing in the way to prevent the cranes from sweeping the entire shop. In the new shop of the Standard Steel Car Company there are two sets of cranes, termed the "Local" and "Express." One set runs on a track 23 ft. above the floor and the other set 20 ft. higher up.

In addition to the large cranes in the Detroit shop there are a

multitude of small cranes of various types throughout the shop. Every machine of any size has its own crane, usually simply a mast and jib provided with an air hoist. These in some cases have the jib long enough so that when the material is taken from one machine it can be swung to the next. In this way the material can go forward without the aid of the main crane. On the erecting floor there is a special overhead structure provided with small hoists at each station, so that each gang of men has its own hoist for handling the material. Most of these in the Detroit plant are what are known as "air engines." One thing which we should have mentioned at the outset is the steel yard, adjacent to the main shop, where the material when it comes in is unloaded from the cars and piled up sometimes 30 ft. high. This yard is swept by two more traveling cranes of the same type as those in the shop.

We will now consider the power necessary to operate this plant. A separate power house is built about 40 ft. away from the main shop, near the center, so that the farthest motor is not over 600 ft. from the generator. The power equipment originally installed consisted of 4 Babcock and Wilcox boilers, 300 h. p. each, with an economizer and induced draft apparatus. In the engine room were three Westinghouse vertical compound engines, 18 by 30 by 16, rated 400 h. p. each, direct connected to Westinghouse generators of 250 kw., each 240 volts direct current. Two Worthington compound duplex hydraulic pressure pumps, two Ingersoll air compressors, horizontal two-stage cross-compound, each of 3 000 cu. ft. capacity. In addition to these there is a condensing apparatus consisting of a Worthington barometric condenser with circulating pump, dry vacuum pump and cooling tower, there being no supply of circulating water except the city supply. The steam pressure carried is 160 lb., no superheat. The electrical apparatus is of 220 volts direct current. The hydraulic system carries a pressure of 1 500 lb. per sq. in. and the pneumatic system 100 lb. There is a large air receiver on the pneumatic system and in the hydraulic system there is also a large receiver for the return water, and two steam accumulators with 50 in. steam cylinders and 16-in. rams. These steam accumulators take up very much less space than the weighed accumumulators and are much more lively, the inertia of the moving parts being so much less. Some two years ago this power plant was increased to about twice its former capacity, an overhead coal bin, ash conveyors, four more boilers, another Westinghouse engine and generator, the same as the others, were added. The

hydraulic system was also increased by adding a triple expansion duplex pump, steam cylinders, 22, 34, and 56 in. in diameter, 36 in. stroke, 8½-in. plungers, rated capacity, 600 cu. ft. per minute, this rating being, of course, against a pressure of 1 500 lb. An additional air compressor was put in last year with a capacity of 6 000 cu. ft. of free air per minute, so that practically this plant has been doubled all around over the original design.

There are many minor features of interest in the power house if we had time to go into them. All the machinery is as far as possible automatic, the pneumatic and hydraulic systems being regulated by the pressure on the system. A safety device on the hydraulic system is arranged so that if by chance anything should break in the hydraulic line, the pump will stop.

Transmission.

Transmission of Power from the Power House. — Entirely across the two spans of the large shop is a tunnel 7 ft. high and 5 ft. wide which carries all cables and pipes from the power house into the shop. The electric cables are carried on brackets overhead, while the pipes are carried on the side of the tunnel. The hydraulic supply main is now 8 in. in diameter and the return 10 in. On all of the hydraulic pressure pipe a special joint is used which is made so that the joints are always absolutely tight and can be removed and taken apart at any time in a few minutes. There is a small steam line used to drive two steam hammers and also to furnish heat in the pipe trenches and tunnels. The hydraulic pipe lines after they leave the tunnel are laid in cement trenches covered with plank and a small steam pipe follows them through each of these trenches, so that if the shop is not working nights and Sundays the mains are kept warm enough to prevent freezing. The lighting of this plant has nothing out of the ordinary, two rows of arc lamps being suspended from the roof in each span. These lights are hung every 20 ft. A permanent runway is provided on the lower part of the roof truss to make these accessible for trimming. The side and center columns of the shop also carry arc lamps, as well as some of the larger machines. In addition to these a large number of incandescent lamps are used around the smaller machines, many of them being attached to flexible conduits so that the operator can push them around to the most suitable position.

Heating and Ventilating.

As this shop covers four acres and is 40 ft. high at the eaves,

it requires a good-sized heating apparatus to take care of it. There is a platform 25 ft. above the floor at the north end, on which are placed several stacks of hot-water radiation having a total of 15 000 ft. of surface. These practically form three sides of a room. On the fourth side there are two large exhaust fans which draw the air from the shop through these radiators and deliver it in galvanized iron pipes to all points of the shop, the main pipe being 60 in. in diameter. The radiators are heated by hot water from the power house. The exhaust steam from the main engines of the power house is passed through a large hot-water heater, and a small Westinghouse engine direct connected to a centrifugal pump causes the water to circulate from the heater to the radiators and back to the heater. The mains carrying this water are 5 in. in diameter. The temperature in these radiators can be carried very close to the boiling point if the weather demands it, or can be carried at as low a temperature as desired, as all the engines are arranged to run either condensing or non-condensing. In addition to the exhaust steam there is a live steam connection controlled by a thermostat. This thermostat can be set to any temperature desired in the heater so that the operating engineer can with two fingers turn the thermostat and change the temperature of the whole shop, or he can set the thermostat as may be required according to the weather. This is an excellent system and practically it works out well except that when three or four doors are open every few minutes, each one of these being big enough to allow a locomotive to pass in and out, and the weather is extremely cold, there may be complaints that the apparatus is not doing its work. Of course, every time a finished car goes out, which occurs every eight minutes, the door is opened and the locomotive takes it away. There is also a supply track where a locomotive comes in to provide raw material, and in addition to these there are a number of small doors and two supply tracks where material is pushed in by hand. Of course these all affect the heat of the shop. There are also more than 1 000 tons of material brought in from out of doors each day which will absorb heat until it comes up to the temperature of the shop. In addition there are ventilators along the entire length of each span, many of which are usually kept open to let off the gas from the rivet furnaces, there being all together twenty-four furnaces consuming oil, and as these have no chimneys the products of combustion rise in the shop. Fortunately these furnaces give out a great deal of heat so that in the winter, even with the opening of the ventilators

and doors, the heating apparatus is usually shut off from eight o'clock in the morning to perhaps five in the afternoon, the heat from the riveting furnaces and other heating furnaces as well as the other hot material throughout the shop being ample to keep it in a very comfortable condition during the day. The heating apparatus is usually run at night, especially if the shop is not working up to its full capacity.

Although the business of steel car building is now practically at a standstill, it has gone forward with very rapid strides with the last few years. The demand for cars of larger capacity and greater endurance has on many roads put the wooden car practically out of service. Although there are at this time 413 000 freight cars on sidings in this country out of service, with the resumption of business there will again be the cry for more cars, and many of these on the sidings are cars that will only be used when better cars are not available. One great field in steel car building has only just been opened up. I refer to steel passenger cars. One of the first orders for steel passenger cars was for the ones used in the New York subway. These were built by the American Car and Foundry Company, in their Berwick plant. Since then quite a few steel passenger cars have been built at this plant. They are now building some magnificent all-steel passenger cars which are 84 ft. in length. This work requires different equipment, a shop differently laid out and a different class of help. Some other shops are now building steel passenger cars. In some cases the railroads themselves have attempted this work. The beginning of every business is costly, and these first large steel passenger cars have been costly; however, we shall soon see shops properly equipped and designed for this work, and the day for the wooden passenger coach as well as the wooden freight car will be soon ended.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by December 15, 1908, for publication in a subsequent number of the JOURNAL.]

THE WATER SUPPLY OF SAN FRANCISCO, CAL.

By C. E. Grunsky, Member of the Technical Society of the Pacific Coast.

[Read before the Society, August 28, 1908.]

Very early in his connection with the affairs of San Francisco, the writer reached the conclusion that the water works of the city should be municipally owned and that the water works as now in service should form the nucleus of the municipally owned system. Without reviewing the entire water supply question, a few remarks on this phase of San Francisco's water supply problems may be acceptable to the society and may also be of some service to the municipality.

It must be remembered, in the first place, that under the constitution of the state of California it is made the duty of the board of supervisors of the city and county of San Francisco to fix water rates, that is to say, to fix the maximum permissible rates, which are to remain in force for one year and no longer. These rates, according to law, as interpreted by the courts, must be such that they will yield a reasonable return on the value of the properties in actual use. No one has yet laid down a rule, acceptable to both municipality and water company, that can be followed in the determination of the value which should be made the basis of the rate fixing. There is great divergence of opinion as to the items that should be included in a valuation and as to the weight that should be given to different methods of valuation. The boards of supervisors have at times been under suspicion of favoring the water company by fixing rates high; at other times the rates established have been so unsatisfactory to the water company that the courts have been resorted to for relief. The annual recurrence of proceedings for fixing rates is a great embarrassment to any public service corporation. It makes the profits of the business more or less uncertain, particularly as injustice may result from ignorance, or prejudice, or from failure of the legislator to appreciate the high moral obligation of being just to the public service corporation as well as to the people. It is not surprising under this system of fixing rates annually that the public service corporation should have been suspected at times of pernicious political activity, or of attempts to bribe public officials.

It would be better if rates subject to review by the courts were fixed for longer periods than one year. Five years would seem a reasonable time for which to assure an income that will encourage the maintenance of good service. In every case of rate fixing full consideration should be given to the facts that called the public service corporation into being, it being generally true that the municipality was in need of the service rendered and was not ready to undertake the construction of municipal works, but was dependent upon private enterprises, which often involved unusual business hazard. This situation is very different from that occasionally presented of a rival concern, duplicating established works, perhaps forcing a combination, but at any rate being in the field only because the prospect of a profit was good.

Under the law as it stands the water company is slow to expand its works. New sources of supply are added only under the compulsion of dire necessity, and sources of water of doubtful reliability are continued in service as long as the municipality will tolerate them. The present status in San Francisco cannot be maintained indefinitely. Either assurance must be given to the water company that it may continue to do business on a fair basis or the city must acquire water works. The first steps on the latter course have already been taken; the supervisors have declared their intention to acquire water works and have asked for propositions to sell established works to the city.

The City Engineer's Presentation of the Problem in Successive Reports.

As city engineer from 1900 to 1904, it was the duty of the writer to investigate the sources of water from which San Francisco might be adequately supplied. Section 1 of Article 12 of the charter of the city and county of San Francisco provides:

"Within one year from the date upon which this charter shall go into effect, and at least every two years thereafter until the object expressed in this provision shall have been fully attained, the supervisors must procure through the city engineer plans and estimates of the actual cost of the original construction and completion by the city and county of water works . . . and such other public utilities as the supervisors or the people by petition to the board may designate."

Acting under instructions of the board of supervisors and of the board of public works a progress report was submitted by the writer on the water supply investigation under date of August 12, 1901. (Municipal Reports of San Francisco, 1900–1901.)

The following extracts from that report relate to the possibility of making the works of the Spring Valley Water Company a part of any municipally owned water works.

"The combination of some new project having its source of supply in the Sierra Nevada Mountains, with the established system, is a possibility which may ultimately come up for consideration, because the most available nearby storage is already utilized. The Spring Valley Water Works has occupied the most available sites for receiving and service reservoirs, and has an established distributing system and an established business.

"There is no reason why these advantages should not be recognized and why the city should not avail itself thereof, if suitable financial arrangements [terms] can be made [agreed upon].

"For the present, however, as a basis for a cost estimate of water works, it is necessary to proceed on the assumption that a new and independent system is required, and the various projects are considered primarily from this standpoint. Should a combination with the established system be found advisable, then the main alteration will relate to conduit capacity, as it would, in such event, not be necessary to at once put into service two pipe lines, each with a capacity of 30 000 000 gal. per day — a single pipe line would suffice. The pipe line would not terminate in San Francisco, but at Crystal Springs reservoir.

"It is desirable that the combined sources of water supply for this city should be capable of yielding ultimately at least 120 000 000 gal. per day, and that any source of supply now to be utilized, or an extension of the established system, should place at least 60,000 000 gal. of water per day at the disposal of the city and that the capacity of water works should be such as to deliver this amount of water to the city at the outset. Any new source to be combined with the established system should be capable of yielding at least 30 000 000 gal. per day and a possible expansion to 90 000 000 gal. is desirable.

"Under an operation of the Spring Valley Water Works, in conjunction with a Sierra supply, a better water than now furnished is to be anticipated, because the peninsula reservoirs could be kept full and ill-effects of low-water stages with exposed flat marginal areas would be minimized. . . .

"Water works now acquired or constructed by the municipality should serve the city for all time. They should be such that other works with Sierra Nevada sources of supply can, whenever required, be combined with them."

On July 28, 1902, a final report was submitted by me as city engineer on the Tuolumne River project for supplying water to San Francisco. (Municipal Reports of San Francisco, 1903-1904.) The following quotations are from that report.

"This project is submitted in compliance with directions of the board of public works as authorized by the board of

supervisors under charter requirements. It is not to be inferred, however, that the city engineer desires to recommend, in submitting this report and a cost estimate, the original construction of an entirely independent water works system as here outlined.

"It must be manifest that such procedure would render valueless certain properties of the Spring Valley Water Works now used in supplying water to this city. As some of these properties can be incorporated in the proposed system to advantage, no other conclusion can be reached than that the interests of the city and of the Spring Valley Water Works are mutual — to have the established works in part, at least, retained in service, and to have the new works supplement that part of the Spring Valley Water Works system which can be thus retained in use. This fact should not be lost sight of in negotiating for the established works as required by law.

"Enough has been said to show that there is no more available source of supply of first quality water with which to supplement the supply of the Spring Valley Water Works than that herein reported upon. Treated from the standpoint of a supplemental supply, however, it should be remembered that the delivery of surplus water would then be into Crystal Springs reservoir instead of into a new reservoir at Belmont, and that a single pipe line with a capacity of 30 000 000 gal. per day would fully meet all immediate requirements. . . .

"The city distributing system would come into use without modification, except the placing of larger mains in some sections of the city to insure the best possible fire protection and the construction of new reservoirs and tanks and an improvement of the pumping facilities. It is thought that an expenditure of $1 000 000 in betterments of this kind would be at once justified if the Spring Valley Water Works' supply were augmented by a supply from the Sierra Nevada Mountains, and that about $500 000 would cover the cost of the receiving reservoir at the House of Refuge lot, and its service mains.

"The appraisements made from time to time of the value of the Spring Valley Water Works properties, as a basis for fixing water rates, may serve as a preliminary guide in determining the financial aspect of such a combination system.

"Should it be carried out, then the conditions under which the nearby sources serve can be materially improved. The Crystal Springs reservoir and Lake Merced can be filled with Sierra Nevada water and kept full. The former will be drawn upon only to the extent of the annual yield or even less, so that less variation in quality of water than at present is to be anticipated."

The availability of various sources of water for use in San Francisco after discussion by the writer as city engineer in the reports already referred to of August 12, 1901, and of July 28, 1902, was further dealt with in a report dated November 24,

1902. (Municipal Reports of San Francisco, 1903–1904.) Extracts from this report relating to the Spring Valley Water Works follow.

" The essential facts relating to the Spring Valley Water Works system and its sources of supply have already been presented in the progress report of 1901. These established works cannot be ignored when an earnest move is made toward the acquisition by the city of municipal water works. In their entirety they are comparable with the other projects that are or have been under consideration.

" No proposal has been submitted for a sale of the properties of the Spring Valley Water Works or any portion thereof to the city, and no definite project for the acquisition thereof has yet been formulated. Such a project would necessarily differ materially in some of the most important features of water works from the other projects under discussion. In the first place, the works have the advantage of being already constructed and in actual use. They are supplying between 25 000 000 and 30 000 000 gal. of water per day. Their distributing system, which, with its 400 miles of pipe, reaches every important establishment in the city, and from which some 50 000 private services are supplied, will either come into use with some other project, or it must be practically duplicated in case that it be not made a part of the municipal system. Other portions of their works, even though their water sources be ignored, would still be valuable to safeguard the supply from distant sources. In the second place the sources of water utilized by the Spring Valley Water Works are near at home. The advantage of short lines of conduits is in a large measure, however, offset by the disadvantage of widely scattered works and the necessity for taking unusual precautions to prevent the pollution of the waters. In the third place, these works can be acquired only after negotiation with present owners and agreement upon a price.

. . . .

" It appears from what has been said in the foregoing pages and the earlier reports herein referred to that the Spring Valley Water Works system, to the extent of its capacity, ranks first in the reliability of service; that the Tuolumne River project ranks highest in the quality and quantity of water; that in the matter of first cost to the city, the advantage should be in favor of the Spring Valley system (a sale at a fair price is to be assumed).

" It is to be added that in the matter of operation it remains uncertain which system, the Tuolumne River project or the Spring Valley Water Works, would have the advantage — the probability being in favor of the newer system.

" Under a combination of these two projects, only a part of the Spring Valley Water Works' properties would be required. Whether such combination would prove of advantage to the city cannot well be determined in advance of an agreement upon the

price at which the necessary parts of the established system could be acquired."

On the occasion of a farewell banquet tendered by citizens of San Francisco to the writer upon his appointment as a member of the Panama Canal Commission, he found opportunity to say in reference to the water supply of San Francisco:

"San Francisco is the only city of its size in the United States which does not own its water works.

"There is no question in my mind that water works municipally owned would be well managed, would enable a reduction of water rates for the same service rendered and would enable the city to provide for its inhabitants the best and purest water obtainable from any source.

"Half a century is but a short time in the life of a city. Looking into the future fifty years, we see in place of our present city a magnificent metropolis — the upper end of our peninsula from bay to ocean densely covered with buildings; the population increased to over one million; Oakland, Berkeley and Alameda clamoring to become a part of San Francisco, if they have not already been made a part thereof; and for this city of the future it is now time to plan the water works, nothing being so essential to the health and comfort of the inhabitants as an abundant supply of pure water.

"In thus looking ahead, it has become apparent to those who have carefully studied the matter that the ultimate source of supply for our water must be in the high Sierra Nevada Mountains. The steps that have been taken to secure water from these mountains is known to all and need not be repeated. Legislation is now pending in Congress which may give to San Francisco the source of supply which comes nearest to being ideal. Whether the project for municipal water works based upon such a source must be carried out at once as an independent project or whether the same must be combined with the present system is the question which will, in the near future, confront the people of this city; but whatever the source of the water, the water works should be municipally owned. The sooner this is brought about the better for the city. Until then the annual trouble and annoyance of fixing the rates to be charged by private corporations will continue, and ill feeling will be engendered between municipal authorities and the officers of the water corporation, and the service cannot be expected to be such as would be rendered under municipal ownership.

"No private corporation can ever do as well for the public, as long as its efforts are being continually discredited and its income is uncertain, as could be done by a competent water department of the municipality. Of all questions relating to municipal ownership of public utilities, none is of such importance, none so urgently pressing, as that of the ownership of the water works. The obstacles which at the present time seem to

be in the way of securing from the federal authorities the reservoir rights of way in a forest reservation, as asked for, are probably not as great as appears on the surface. The main opposition comes apparently from the irrigation districts which are dependent upon water from the Tuolumne River. These districts are not now in a position financially to increase the flow of water into their canals by means of storage in the high mountains. They look forward, however, to the time when the increasing areas under cultivation, the increasing demand for water which will be necessary for irrigation, will make storage in the high mountains desirable. These districts at the present time look with alarm upon the taking of any water from the Tuolumne River for the benefit of San Francisco. As a matter of fact, however, the water to be taken by San Francisco is not water which would be of any benefit to the districts, being only a small portion of the waste flood waters of the river which now flow unused to the sea.

"San Francisco would, then, be depriving the districts of nothing except merely of the opportunity to store water for their own use when the time for such storage shall have come, in those two particular reservoir sites for which San Francisco has made application. To these reservoir sites San Francisco has as good a right as any person or any other section of the state. San Francisco has made the first application for them and San Francisco must take every step necessary from time to time to protect her rights and to be allowed to use these storage sites for the impounding of water if such storage be ever permitted in the forest reservation. But the flood waters impounded when the storage works shall have been completed will for many years — from a quarter to half a century — be far in excess of the amount actually required to supply the needs of San Francisco and her inhabitants.

"There will be a large surplus of water in the reservoirs, and this surplus can be liberated at times when it will be of greatest benefit to the lands in San Joaquin valley upon both sides of Tuolumne River requiring irrigation. It is to be anticipated that in these irrigated districts the soils will gradually become saturated with water, and after a number of years the water required per acre irrigated will gradually decrease. At the same time the districts will be decreasing their bonded indebtedness and the time will come when they will feel financially able to carry out storage works of their own, and then they, like San Francisco, will be compelled to apply for the privilege of utilizing storage sites in the forest reservation.

"When this situation is thoroughly understood by the irrigation districts, instead of opposition, San Francisco should receive their help.

"The more thoroughly the available sources of water supply are investigated, the more it will become apparent that the solution of the water question lies along the lines that have been indicated and that the time has come for determining to what

extent the established water works are to enter into the ultimate water supply project. I trust that the day may not be far distant when the municipal ownership of water works will be an accomplished fact."

ACQUIRING CONTROL OF THE RESERVOIR SITES ON TUOLUMNE RIVER.

Among the sites for the storage of water in the Sierra Nevada Mountains which have been examined and reported upon by the engineers of the United States Geological Survey are Lake Eleanor and the Hetch Hetchy Valley. Both of these reservoir sites are in the watershed of Tuolumne River. The latter is on the main stream. Writing of this reservoir site in the twenty-first annual report of the Geological Survey, Mr. J. B. Lippincott, of Los Angeles, then the assistant in charge of the hydrographic work of the Survey in California says:

"The valley proper is about three and one-half miles long and of a width varying from one quarter to three quarters of a mile. The rugged granite walls, crowned with domes, towers, spires and battlements, seem to rise almost perpendicularly upon all sides to a height of 2 500 ft. above this beautiful emerald meadow. . . . It was visited in May when the snows on the glacier meadows on the higher altitudes were rapidly melting, and the river was bank full and overflowing the lower part of the valley. The water is here dammed up, owing to the narrow outlet between high mountains of granite rock."

The Tuolumne River, as a source of water for San Francisco, with Lake Eleanor and Hetch Hetchy Valley as reservoir sites, was investigated preliminarily and reported upon by the city engineer in 1900. In January, 1901, the first step was taken toward acquiring reservoir rights-of-way in the watershed of Tuolumne River. The following extracts are from a communication addressed by the writer, at that time city engineer, to the board of public works, under date of January 23, 1901.

"The water supply investigation has been advanced sufficiently to justify the conclusion that San Francisco will ultimately be in need of a source of water from the Sierra Nevada Mountains either with or without the utilization of the established works and nearer sources. Preliminary examinations demonstrate the practicability of bringing in a supply from such a source.

"Under these circumstances the acquiring of the necessary water rights and storage facilities should not be overlooked. They should be secured as opportunity offers to the end that when the time comes works may be established adequate to meet the future needs of this city.

"To prevent certain privileges and rights that may be of vital importance from falling into the hands of speculators, private individuals or private corporations adverse to the interests of this city, and as the regulations of the Department of the Interior permit the filing of applications and the setting apart to individuals or corporations of reservoir sites in the public domain, application should at once be made to the Secretary of the Interior to set apart for the use of this city the Hetch Hetchy Valley and Lake Eleanor reservoir sites."

Applications for the reservoir rights-of-way here suggested were necessary because, although in each case some of the required land was in private ownership, both of the dam sites are on the public domain and some government land would be flooded by the construction of dams. The right to use land for the reservoirs and the right to erect dams could be granted only by the Secretary of the Interior.

The first steps that were taken in this matter could not be made public without endangering the success of a movement for Tuolumne River water. Under joint action of the board of public works and the mayor, James D. Phelan, the city engineer was authorized to include in the surveys on the Tuolumne River such right-of-way descriptions at Lake Eleanor and in Hetch Hetchy Valley as were requisite in making formal application for the reservoir sites.

It was found upon inquiry that there was no precedent for an application by a municipality for a right-of-way in a national forest reservation. The advice received in the matter was that it would be safer to let an individual make the application and to let rights acquired thereunder be subsequently assigned to the city. This procedure had the advantage, too, that it obviated the necessity for publishing the intent of the city to apply for rights that were apparently to be had for the asking. Interference with speculative interests was thereby in all probability avoided. Mayor Phelan was obviously the proper person to make the application, but he had to do it as a private citizen. Subsequently, he made a complete transfer to San Francisco of all rights that might be acquired under his application. What Mayor Phelan did in this matter is what was asked of him by the city engineer and by the members of the board of public works. It is no more and no less than would have been expected of any other mayor.

The surveys were so far advanced that in October, 1901, an application could be made for the two reservoir sites, and the necessary papers were filed in the Stockton land office. More

than a year elapsed before word was received from Washington that the application for both rights-of-way had been rejected on the ground that the law made it obligatory upon the Secretary of the Interior to preserve the natural wonders in national parks. The city was advised by the Secretary of the Interior that congressional action would be necessary to make the utilization of the two sites possible. The usual opportunity for requesting a review of the decision was, however, given to the city. A review was granted and the city, through its city attorney and its city engineer, presented its case to the Secretary of the Interior in March and April, 1903.

Until this time there had been no opposition manifest to the acquisition of water rights and reservoir sites by the city, although there had been no attempt to conceal the city's purpose after the application for reservoir rights-of-way had been filed.

In July, 1901, notices of claims to water had been posted in Tuolumne County and filed for record in the name of Mr. Phelan; in October, 1901, the filing in the land office was made and under date of July 28, 1902, the city engineer submitted a report on the Tuolumne River water supply project. In this report full explanation of the right-of-way applications was made. The matter had also received more or less attention by the newspapers.

At the hearing in Washington it developed, however, that the Spring Valley Water Works were represented by their manager in opposition to the city's application. Representation was made by him, not only that the city did not need to go to the Sierra Nevada for water, but that the water of the Tuolumne River could not be used by San Francisco without detriment to a large farming community which would ultimately require all the water of the river. At this hearing it also became apparent that the two irrigation districts had suddenly been awakened to a belief that the proposed water storage by San Francisco was a serious menace to the prosperity of the districts. So recent was this awakening that it was manifested by telegraphic communications from each of the two attorneys of the districts to the Secretary of the Interior.

It developed at this hearing, too, that the long time which had elapsed since the city filed its application had given private parties the opportunity to make surveys and file or offer for filing a rival application for the Lake Eleanor reservoir site. Mr. William Hammond Hall appeared as the representative of persons whom he would not name, and made the point that the

city had forfeited rights to priority in the matter of Lake Eleanor because it was disclosed by the cost estimate and general plans of the proposed works for utilization of Tuolumne River water that Lake Eleanor was not to be included as a part of the Tuolumne River project. The city needs both sites and no other conclusion is possible from a reading of the city engineer's reports than that the only question was the order in which they should be brought into use. The fact that a Lake Eleanor dam was not projected for immediate construction is no evidence that the same was eliminated from consideration as an essential ultimate requirement. The immediate construction of both reservoirs was not recommended for financial reasons.

The review of the Secretary of the Interior's decision did not lead to any modification thereof. The first conclusion that he could not grant the required privilege to San Francisco without legislation was confirmed. But the matter was not allowed to drop. The President and Congress were memorialized, and bills were introduced providing for a grant to San Francisco of the necessary lands at both reservoir sites.

The situation at this time is clearly set forth in the memorial adopted by the board of supervisors, on January 4, 1904, which is as follows:

"The board of supervisors of the city and county of San Francisco respectfully presents the following memorial to the President and Congress of the United States:

"*Whereas*, Under the provisions of the constitution of the state of California, 'the use of all water now appropriated, or that may hereafter be appropriated, for sale, rental or distribution, is . . . declared to be a public use, and subject to the regulation and control of the state, in the manner to be prescribed by law'; and the Civil Code of the state, in paragraphs 1410, 1411, 1413 and 1414, declares,—

"'The right to the use of running water flowing in a river or stream, or down a canyon or ravine, may be acquired by appropriation";

"'The appropriation must be for some useful or beneficial purpose, and when the appropriator or his successor in interest ceases to use it for such a purpose the right ceases';

"'The water appropriated may be turned into the channel of another stream and mingled with its water, and then reclaimed; but in reclaiming it, the water appropriated by another must not be diminished;'

"'As between appropriators, the one first in time is the first in right';

"*Whereas*, It has become manifest that the water supply of this city must sooner or later be increased by the addition of a

supply from the Sierra Nevada Mountains, and the securing of this supply should not be delayed;

"*Whereas*, The city and county of San Francisco proposes to appropriate for the use of its inhabitants, as authorized by law, water of the Tuolumne River, it having been found, as the result of the exhaustive investigations by the board of public works of San Francisco that this river is the best and most available source of supply to meet the immediate and future requirements of this large, important and rapidly growing city;

"*Whereas*, This appropriation of water is to be made without interference with vested rights, and this can be accomplished only by the storage of large quantities of the flood flow of the river and its tributaries;

"*Whereas*, The sites for the storage of the waste, storm or extra-seasonal waters of the Tuolumne River are located within a forest reservation generally referred to as a national park, and the Secretary of the Interior being authorized and empowered by the act of Congress, approved February 15, 1901, to permit the use of rights-of-way through the public lands, forest and other reservations for such reservoirs used for the supplying of water for domestic, public or any other beneficial uses to the extent of the ground occupied by such reservoirs, applications were duly made for two reservoir sites, one on the Tuolumne River, at the point known as Hetch Hetchy Valley, and one at Lake Eleanor;

"*Whereas*, These applications for reservoir rights-of-way were denied by the Secretary of the Interior, who points out that, as viewed by the Department of the Interior, 'the application is confronted by legal embarrassments which appear to be surmountable only by the exercise of the legislative power of the government';

"*Whereas*, The specific reason of the rejection of these applications is in part stated by the honorable Secretary of the Interior as follows: 'The act of October 1, 1890, makes it obligatory upon the Secretary of the Interior to preserve and retain the "natural curiosities and wonders" in the park in their "natural condition." This provision of the act which establishes the park remains in full force, not having been repealed or modified by the act under which this application is made nor by any other legislation.

"'It is contended that the appropriation of Lake Eleanor and Hetch Hetchy Valley for great reservoirs for the proposed storage of water would enhance rather than detract from their natural beauty, but this is not material in view of the law which commands the Secretary of the Interior to preserve and retain them in their natural condition if they are "natural curiosities."

"'There may be a difference of opinion as to what natural objects may be justly considered as being within the meaning of this provision of the law, but there can be no doubt about the duty of the Secretary of the Interior if, in his judgment, they are such natural curiosities or natural wonders so contemplated by the act';

"*Whereas*, Both of these sites have been recognized by the Department of the Interior as desirable and available for the storage of the flood flow of mountain streams, as demonstrated by the reports of the United States Geological Survey, in which these reservoir sites are repeatedly referred to. A plat of the Hetch Hetchy Valley was submitted to the Secretary of the Interior by the United States Geological Survey and its reservation from entry or settlement according to law was asked for under date of February 27, 1891. [See opening statement and page 36 of Part II of the Twelfth Annual Report of the United States Geological Survey.] A further report upon the availability of this reservoir site, with a study of the works necessary at the dam-site, are contained in the Twenty-first Annual Report of the United States Geological Survey, pages 450 to 465, in which, on page 459, it is stated: 'Another purpose which this dam and reservoir might be made to serve would be to furnish the city of San Francisco with an unfailing supply of pure water. Without entering into details, it will suffice to say that the dam and reservoir as proposed would insure a supply in the driest years of 250 gallons per diem per capita for 1 000 000 people.' Lake Eleanor and the segregation of its lands for reservoir purposes is referred to in Part II of the Eleventh Annual Report of the United States Geological Survey, page 157, on the plate between pages 160 and 161, and on page 167; also in the Thirteenth Annual Report, Part III, page 402;

"*Whereas*, It is not conceivable that the maintenance of a forest reservation with an area of about 1 500 square miles is to interfere to any material extent with the development of water for useful purposes, particularly when such utilization introduces into the park a new lake about 2 square miles in area and enlarges a second from less than one half to nearly two square miles, enhancing the natural beauties of the park instead of detracting from them;

"*Whereas*, Neither of the two sites in question is now accessible by wagon road, and will never be visited by any considerable number of persons except in the months, July, August and September, when the stage of water in the lakes will be high;

"*Whereas*, The use to which the water is to be put is the highest possible beneficial use;

"*Therefore*, this board memorializes the President and Congress of the United States to pass such laws as may be necessary to grant to the city and county of San Francisco the right to use the reservoir sites heretofore applied for."

In addition to this a direct appeal was made to the President for the city by Mr. Marsden Manson, now city engineer, and resulted in the obtaining of an opinion from the Attorney-General of the United States to the effect that the power to grant rights-of-way as applied for by San Francisco was vested in the Secretary of the Interior. The bills before Congress were not, therefore, pressed.

In the meanwhile Mr. James R. Garfield succeeded Mr. E. A. Hitchcock as Secretary of the Interior, and in the light of the Attorney-General's opinion a request was presented to him to have the matter reopened. This request was granted and after many conferences and long deliberations San Francisco has been granted the rights asked for, subject, however, to such control on the part of the United States government as will protect the prior rights of the irrigation districts.

In order that the situation may be clearly understood, a brief description of the works now in use and of the proposed Tuolumne River project is here given.

Water Works hitherto in Use. Sources Developed.

Practically the entire city is now supplied with water by the Spring Valley Water Company. The service of the Visitacion Valley Water Company, of the John Center Works which were of such great service in checking the southerly advance of the great fire in 1906, and of a few other minor concerns, is so small that it need not be further considered in this discussion.

It is noteworthy, however, that for various purposes water in large quantity is drawn from the bay and the ocean, thereby decreasing measurably the demand on the established service. Various concerns use salt water for condensing. The Olympic Salt Water Company supplies some water for this purpose and some for bathing, drawing its supply from the Pacific Ocean. The power stations of the United Railways are all supplied with salt water drawn from the bay for cooling purposes. The city is now about to construct a high-pressure fire protection system which will draw water from wells and from the bay.

For use in Golden Gate Park water is pumped from wells at two points: at a pumping station near H Street and Thirteenth Avenue for general use, and at a point near the ocean by a Dutch windmill for a supply to the chain of lakes and other uses. The Presidio draws water from wells at Mountain Lake.

The fact that a large amount of salt water and locally obtained water will always be used for various purposes; that the climatic conditions, particularly the cool weather and fogs of summer, keep down the water consumption, and the fact that restricted building areas will compel the crowding together of residences and will keep down the area of lawns and gardens — these facts all contribute to make the water requirement of San Francisco relatively small. It can probably, without undue restrictions upon the water consumer, be kept at about 80 gal. per inhabitant.

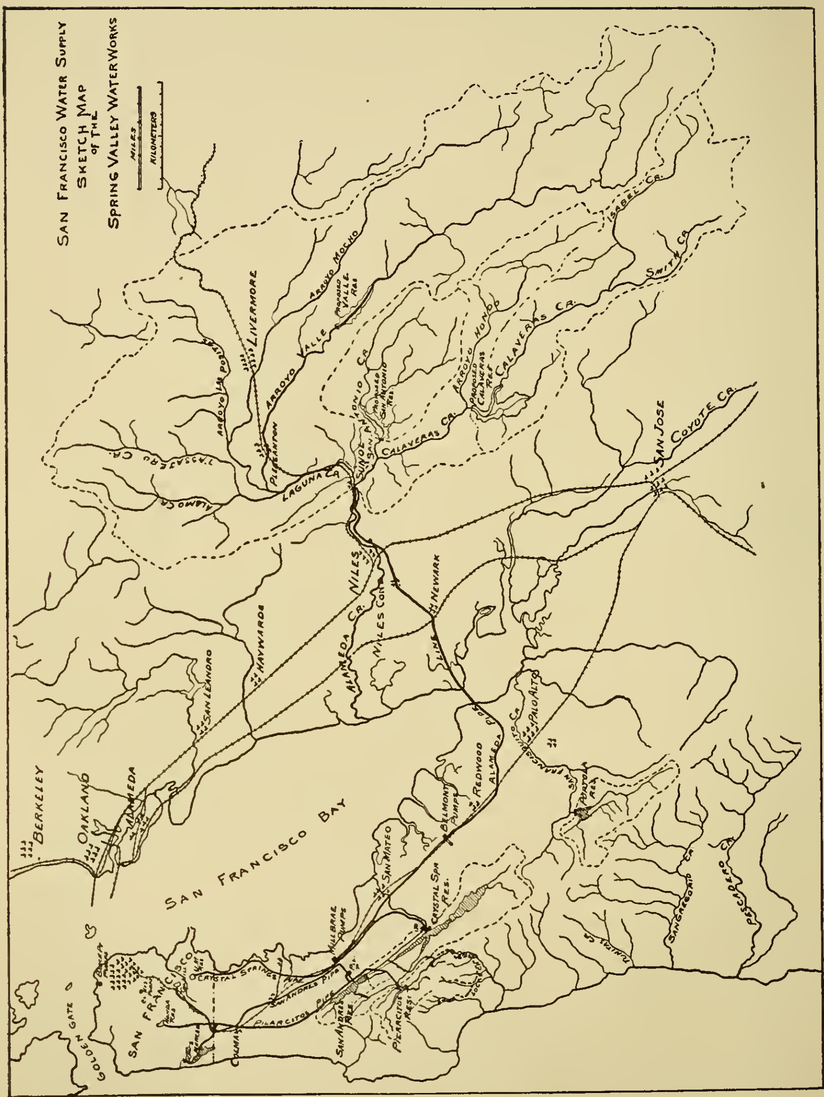
In the early days of San Francisco's history, water for drinking purposes and domestic use was peddled about the streets in water wagons. Fire protection was afforded by fire engines operated by hand and by cisterns which were filled with salt water pumped from the bay.

About 1858 Lobos Creek water was brought into the built-up portion of the city by the San Francisco City Water Works. The flume around Fort Point, at an elevation of about 20 ft. above the ocean, which was in service until 1895, will be remembered in this connection. This source of supply remained in use, therefore, nearly 40 years. Lobos Creek was not finally abandoned, however, as a possible source of water until the year 1901.

The construction of the City Water Company's works, which included a pumping station at Black Point and a reservoir on Russian Hill, was quickly followed by the organization of a rival company. The projector of this rival company was Geo. H. Ensign, who controlled certain water rights deemed to be adequate for the intended purpose. Among the sources that had been or that were being drawn upon was a spring located somewhere on the slopes of Clay Street Hill in a depression then known as Spring Valley. This explains the name adopted by the company. Under date of January 1, 1865, the San Francisco City Water Works sold out to the Spring Valley Water Works, and the latter corporation five years ago sold out to the Spring Valley Water Company.

As the city grew the nearest sources of water were one by one abandoned and new sources farther away from the center of population came into use. As early as 1863 to 1865 the Pilarcitos reservoir was constructed and added to the system. It came into use as a small reservoir formed by a low earth dam, which was submerged and went out of service when the present higher dam was completed in 1869. San Andres reservoir came into use in 1870, and the Upper Crystal Springs or Cañada de Raymundo reservoir, now a part of the Crystal Springs reservoir, about 1878. Merced Lake was added to the water works in 1877 and 1878. The explosion of a boiler wrecked the pumping station at this lake in 1885, and it remained out of use thereafter until 1891, when the present pumping station came into service. Alameda Creek water, the right to which had been acquired in 1875 by the purchase of the Alameda Water Company's properties, was first brought across the bay in 1888. The diversion was then at the Niles dam. Seven years later the point of

GRUNSKY. PLATE I.



diversion was changed to Suñol valley, and the filtration feature was added to this part of the water works system. The amount of water diverted from the creek was materially increased at that time. The construction of the Crystal Springs concrete dam on San Mateo Creek was commenced in 1886, and work on this structure was continued until 1892. Lobos Creek went out of use with the destruction by landslides of the flume around Fort Point in 1895. It was to be again added to the system in 1901, but yielding to the wishes of the city authorities the water company finally abandoned it as a source of supply in the same year.

Pilarcitos reservoir is fed by a creek of the same name which courses down the ocean slope of the Montara spur of the coast range. It is located about 12 miles south of the south boundary of San Francisco. The elevation of the water surface of a full reservoir is 682 ft. above San Francisco city base (this base is about 10 ft. above mean sea level). The reservoir is formed by an earth dam 90 ft. high and 730 ft. long on the crest. Its surface area when full is about 105 acres. The storage capacity of the reservoir is 940 000 000 gal.

Until destroyed by the earthquake of 1906, a wrought-iron pipe, 30 in. in diameter, brought the Pilarcitos water into San Francisco. Since that time the Pilarcitos water is allowed to flow into San Andres reservoir and reaches the city through the San Andres pipe. The watershed tributary to the Pilarcitos reservoir is 3.5 sq. miles, to which, by side hill flume, about 1.4 sq. miles more has been added.

San Andres reservoir is about two miles nearer to San Francisco than the Pilarcitos reservoir. It is located on the bay side of the mountains and at a lower altitude. Its elevation when full is 435.6 ft. above city base and the surface area of the reservoir is 475 acres. This reservoir lies on a small branch of San Mateo Creek and there is tributary to it, naturally, a watershed having an area of 4.1 sq. miles. To this there was added in 1897, by a tunnel known as the Davis Tunnel, an area of 0.9 sq. miles cut-off from San Mateo Creek. The Locks Creek line of flume and pipe, which was in service until about 1899, added run-off waters from 3.4 sq. miles of additional area. Thereafter for several years all of the Locks Creek line above Apanolio Creek was out of service. Now the New Locks Creek line is in the main an interceptor of Pilarcitos water below Pilarcitos dam, including wastage from Pilarcitos reservoir. The area at present made partially tributary to Lake Andres by this conduit includ-

ing 1.5 square miles of San Mateo Creek below the Davis tunnel, may be taken at about 3 sq. miles. The San Andres dam is an earth embankment, lying just on the edge of the fault line on which there was a horizontal movement of about 7 ft. at the time of the earthquake of 1906. The abutment of the dam is cut by the fault. The dam has remained intact and uninjured. The dam is 90 ft. high, and has a crest length of 990 ft. The San Andres reservoir when full holds 5 723 000 000 gal. of water. Waste water, when there is any, flows from this reservoir into the Crystal Springs reservoir. The water from this reservoir flows through a tunnel 2 820 ft. long into a measuring box, then into a screen house, where it is passed through cloth screens. It is thereupon carried in 28 849 ft. of 44-in. wrought iron pipe, 40 185 ft. of 30-in. pipe and 1 400 ft. of 37-in. pipe, the latter across a creek between Baden and Colma, to San Francisco, where delivery is made into the College Hill reservoir.

The Crystal Springs reservoir is the largest of the storage reservoirs on the peninsula. It lies about 4 to 8 miles further from San Francisco than the San Andres reservoir. It is formed by a dam across San Mateo Creek just below the point where the creek receives the waters of the Cañada de Raymundo from the south. The reservoir as it now exists is formed by a massive concrete dam. This was constructed in the years 1887 to 1892. The dam is to be raised 30 ft. at some time in the future. As it now stands it has a height of 146 ft. and the reservoir formed by it has a capacity of about 18 900 000-000 gal. The elevation of the top of the present structure is 280 ft. above city base.

Some years before this dam was constructed, as already stated, there had been constructed the Upper Crystal Springs or Cañada de Raymundo dam. This dam is of earth. On its crest, which is slightly higher than the crest of the Crystal Springs concrete dam, is a road. Upon the completion of this dam in 1878, and for seven years thereafter, the water stored by it was pumped into the San Andres system. But in 1885 the 44-in. Crystal Springs pipe line was completed and water then flowed by gravity from the Cañada de Raymundo reservoir to the University Mound reservoir in San Francisco. The earthquake of 1906 split the dam crosswise, one end of the structure being moved about 8 ft. with reference to the other. At the time of this earthquake, April 18, 1906, the water level on both sides of the dam was the same. There was, therefore, no flow of water through the structure and no damage from this

cause. The dam has been of no importance as a feature of the water works since the construction of the concrete dam.

The Crystal Springs concrete dam is about 600 ft. long on top. It is arched upstream. About 164 000 cu. yd. of concrete were required in its construction and in the construction of a deep cut-off wall across a low gap north of the hill against which the north end of the dam abuts. At the elevation of the present top of the dam the water surface area of the reservoir is about 1 300 acres. The area of the watershed tributary to the Crystal Springs reservoir, not including the area cut off by the Davis tunnel, is about 23.2 square miles. Of this area about 12 square miles were tributary to the Upper Crystal Springs reservoir. The conduit from the Crystal Springs reservoir to San Francisco is a 44-in. wrought-iron pipe. The route followed by this pipe is along the bay shore. It crosses a long stretch of swampy ground near Baden and lies upon hilly and otherwise difficult ground at Sierra Point. One spur of the hills is here pierced by a tunnel 300 ft. long. After crossing Visitacion valley the conduit is again in tunnel 2 145 ft. long. It discharges into University Mound reservoir. The total length of this conduit is 87 066 ft.

Among the works on the peninsula south of San Francisco that are productive of water is the Locks Creek line. Originally this aqueduct included a long conduit skirting the ocean slope of the mountains into which water from a number of small creeks was admitted.

The upper end of the conduit was at Locks Creek. About 1897 the upper part of the works down to Apanolio Creek and in 1901 another section below this creek, went out of service. Since 1901 the lower part of this line as reconstructed has alone been in use. At the head of these works as now in service on Pilarcitos Creek, about a mile below the Pilarcitos reservoir, is a stone dam about 35 ft. high. This dam diverts the flow of Pilarcitos Creek into a flume. To the natural flow of the creek there is here added some water intercepted by a hillside flume, which discharges into the basin above the stone dam. The overflow or waste water from the Pilarcitos reservoir reaches the stone dam and opportunity is thus afforded for turning it into San Andres reservoir. The flume from the stone dam carries the water about three quarters of a mile to a tunnel 3 200 ft. long, which pierces the ridge between the Pilarcitos and the San Mateo drainages. The water, after passing through this tunnel, is carried in a flume about 2 miles to the point where

San Mateo Creek is crossed from west to east. A second tunnel carries the water through the ridge between San Mateo and San Andres valleys. This tunnel is about 3 530 ft. long. At the westerly or San Mateo end of this tunnel the Locks Creek flume is joined by a flume from the north which adds San Mateo Creek water that has been diverted by a concrete dam from that creek. About 1.5 sq. miles of the watershed of San Mateo Creek lying next below the area for which Davis tunnel is an outlet are thus made partially tributary to San Andres reservoir.

The water consumption from the Peninsula reservoir system has been about 18 000 000 gal. per day. This is in round numbers at the rate of 530 000 gal. per day per sq. mile of tributary watershed. The amount of water wasted has been relatively very small, due to the large capacity of the reservoirs when compared with watershed areas. In years of ordinary rainfall Pilarcitos reservoir is the only one which is likely to be filled to overflowing, but as explained, nearly all of the surplus is conserved by the interceptingworks which carry it into San Andres reservoir. The overflow from the San Andres reservoir goes into the Crystal Springs reservoir, and the Crystal Springs reservoir has been full to overflowing only twice in its history, in 1889 and in 1895. The above-noted water production of 530 000 gal. per day per sq. mile may, therefore, be accepted as very nearly the normal for this region, in which 43 in. per year is the normal fall of rain.

When the amount of storage on the peninsula is compared with the amount of storage usually provided to equalize the flow of streams on the Atlantic coast, it seems large, but the need for the relatively large reservoir capacity results from the peculiarity of the climate. The rainfall records show that there may be two or even three years in succession in each of which rainfall is so light that there is very little run-off. To tide over such periods that are unproductive of water a large supply of water must be held over from the preceding seasons of more copious rainfall. Col. G. H. Mendell, who gave the subject much thought, reached the conclusion, as laid down in his report of 1877 on the San Francisco water supply, that so long as the city relied upon the coast range sources of supply the storage capacity of the reservoirs should be a 900 days' supply.

When a reservoir is located on a stream whose flow every year is adequate to fill it, this rule is, of course, without force. But even after some of the larger rivers of the state are made tributary to the established works, the storage of water in large quantity near the city is essential to make the service reliable.

The matter of securing other sites has been investigated and one at Belmont was selected for use as a feature of the Tuolumne River project. It goes without saying that the use of this site should only then be contemplated if the city fails to come to an understanding with the Spring Valley Water Company. The water company in extending its works from time to time naturally occupied the best and most available sites. The storage reservoirs now in use, particularly with the Crystal Springs dam raised to the full proposed height, will be adequate to meet every requirement.

The peninsula sources of water, which as described flow by gravity into San Francisco, are supplemented by Lake Merced. This lake lies close to the Pacific Ocean, just north of the southerly line of San Francisco. The elevation of its water surface at all stages is above sea level. The water in the lake, for the most part, is the outflow from the sand deposits that lie within the lake watershed. The surface run-off, which formerly reached the lake, is now intercepted and turned through a tunnel, past the lake into the ocean.

The lake has two arms that were originally connected by a narrow strip of water. They are now separated from each other by an earth dam. Structures have been built for the interconnection of the two lakes so that one pumping station may draw upon the water of both lakes. The surface area of Lake Merced is about 330 acres. When full its available contents are about 2 000 000 000 gal. The lake is not attractive as a source of water for domestic use, but for many years its water has been used mixed with the waters from Pilarcitos and San Andres reservoirs. It is protected against pollution by a system of works which intercept and deliver into the ocean the surface run-off from the inhabited portions of its watershed. These works include a brick conduit and tunnel from near the head of the south arm of the lake to the Pacific Ocean and a long flume from Ocean View; also a conduit for the Ocean View sewage. The large capacity and nearness of Lake Merced to the place of use will always make it a valuable addition to a municipal supply, even though no water be drawn from it except in case of emergency. When a Sierra Nevada water is added to the city water supply system the surplus should be allowed to flow into the Crystal Springs reservoir and into Lake Merced, thereby keeping these reservoirs as nearly full as practicable, and incidentally improving the quality of the stored water in each.

The value of Lake Merced as an emergency supply, if water

production may be considered, is not fully measured by its storage capacity, because the experience of the past indicates that it may be relied upon for a continuous supply of water amounting to about 3 000 000 gal. per day. The pumping station at Lake Merced has a capacity of about 7 000 000 gal. per day. It delivers water into the conduit that brings the water of Pilarcitos reservoir into the city.

So long as Lake Merced remains in use as a source of water, the human activities in the tributary watershed should be kept down as much as possible. Notwithstanding the works for the interception of surface drainage from the south and sewage from the east, there is a menace due to such activities that should be kept at a minimum. There is good reason, therefore, for preserving the lands near Merced Lake, if the city ever acquires them, as a park, whereby population can be excluded from the greater portion of the drainage basin and good police regulations can be enforced.

In 1887 it became apparent that the peninsula sources of water as then in use were inadequate to meet the demand for water. The immediate extension of the works to the easterly side of the bay of San Francisco was, therefore, determined upon. Rights to water in Alameda Creek had, as already stated, been secured, as early as 1875, by purchase of properties of the Alameda Water Company. This purchase included, besides these water rights, a part of a reservoir site on Calaveras Creek.

The Alameda Creek works, as commenced in 1887 and completed in 1890, were for the diversion of the natural flow of Alameda Creek at a dam about 2½ miles above Niles, and the delivery of this water by gravity flow through a long wrought-iron pipe conduit into a small receiving reservoir at Belmont, from which it is pumped through a pipe to Burlingame into the main from Crystal Springs reservoir.

The capacity of the works as thus constructed was about 7 000 000 gal. per day. They remained in service at this capacity for about 10 years, then the system was changed, by the addition of works higher up on Alameda Creek, and as a result of the change, which included a greater head to force water through the conduit to Belmont, the capacity of the Alameda Creek system was raised to about 10 000 000 gal. per day, at which it remained until further increased in 1903.

As now in use, the works include filtration in a large natural gravel deposit of the Suñol Valley. Water of Laguna (Alameda) Creek and of Calaveras Creek is brought within reach of this

gravel bed by a system of ditches. It sinks from these and from the natural channels into the gravel beds. It is intercepted in these gravel beds by a timber filter gallery placed in the bottom of a deep open cut, which is about one-half mile long and terminates in a concrete sub-surface aqueduct into which the water is also directly admitted through many small openings in its side walls. The concrete aqueduct is about 3 000 ft. long. It has a side feeder intended to more completely intercept the water coming down the creek channel. At its lower end it is connected with a gallery or conduit leading across Alameda Creek, from right bank to left bank, within the concrete diverting dam which has been placed across the Alameda Creek at the lower end of the Suñol Valley. This diverting dam is primarily intended to check any outflow from the gravel beds of Suñol Valley at less elevation than the crest height of the dam. The gravels are thus made to serve in some measure as a reservoir. The dam may also be used, if conditions require it, to divert the creek water directly into the conduit which takes it from this point down the Niles Cañon to the head of the pipe line.

The water from the Suñol Valley gravels, after crossing Alameda Creek as described, is carried by tunnel and flume along and in the mountain slopes on the south side of the cañon for a distance of 5 miles to a screen house, at elevation 180 ft., and there enters the pipe which conveys it to Belmont. About 3 miles of the 5 are in tunnel. The total length of the Alameda Creek pipe line from the screen house near Niles to the junction with the Crystal Springs main is about 29 miles. The pipe to Belmont is 36 in. in diameter, except where a slough and the Bay of San Francisco are crossed near and at Dumbarton Point. At each of these two places the water was carried in two 16-in. submerged pipes until 1902, when two submerged 22-in. steel pipes were added. The pressure main from the Belmont pumps to Burlingame is 36 in. in diameter. From Burlingame to Millbrae the 44-in. Crystal Springs main was paralleled in 1903 by a 54-in. main ni which the Alameda Creek water can be carried apart from the Crystal Springs water to the Millbrae pumping station and by the pumps there located can be forced into the San Andres main. The water supply from Alameda Creek is reinforced by the flow from 22 artesian wells in Livermore Valley near Pleasanton. A line of wells has been bored across the lower end of the Livermore Valley to the gravel beds, from which they bring to the surface about 7 000 000 gal. of water per day. This water is discharged into the creek and flows therein to the head

of a ditch which leads it into the Suñol Valley along or near the upper edge of the Suñol gravel deposits. The yield of the Alameda Creek system is now about 15 000 000 gal. per day.

There are a number of pumping stations connected with the water works. Some of these will be referred to in presenting salient features of the distributing system; others deserve special notice because of their peculiar function in transferring water from the lower to the higher levels.

The function of the Belmont pumps, as already explained, is to deliver Alameda Creek water either into the Crystal Springs main or to feed the Millbrae pumps for delivery into the San Andres main. The pumps at the Belmont station first went into service in 1888. New pumps were added in 1903. The present aggregate capacity of the pumps at this station is about 23 000 000 gal. per day.

The Millbrae pumps were installed with a capacity of about 16 000 000 gal. per day to force some of the water arriving in the Crystal Springs main into the higher San Andres main. Since the completion of the pressure main from Belmont to this station the Millbrae pumps serve also to send Alameda Creek water into the San Andres main.

The Pilarcitos pumps are located at the lower end of the outlet tunnel of the San Andres reservoir. The function of these pumps is to deliver San Andres water into the Pilarcitos main. Their capacity is about 4 000 000 gal. per day.

At Ocean View is an emergency pump of small capacity which serves the same purpose but has been but little used, if at all.

At the Crystal Springs dam is a pumping station which may be used to lift Crystal Springs water into a flume which carries it northerly into San Andres Lake. The capacity of the pumps here located is about 12 000 000 gal. per day.

The pumps at Lake Merced are connected with the San Andres and Pilarcitos mains in such a way that without loss of pressure the water from the San Andres main can be pumped into the Pilarcitos main. By suitable interconnection of pipes the two pumps at Lake Merced can be made to draw simultaneously either upon the lake or upon the San Andres main, or one pump can be fed from the main while the other draws its supply from the lake. The lake water, as already explained, is pumped into the Pilarcitos main and flows into Lake Honda receiving reservoir. The capacity of the Lake Merced pumps is about 7 000 000 gal. per day.

Before passing on to a description of the city distributing system it should be stated that all of the water, before delivery into the city receiving reservoirs, is screened. The screen house, near Niles on the Alameda conduit, is equipped only with wire mesh screens to remove occasional leaves and the like blown into the flume by the wind. The water which reaches University Mound reservoir all passes through a screen house there located. At this screen house, as at those on the San Andres line and at Lake Honda, the water is made to pass through ingeniously arranged screens of cheesecloth. After a set of screens has been in service about 1½ hours, the water is turned off and the screens are cleaned with a jet of water. Particles of vegetable matter, principally algæ, are removed from the water in this way. The screen house on the San Andres pipe line is located at the lower or easterly end of the outlet tunnel of San Andres reservoir. At Lake Honda is a screen house for the treatment of the water arriving in the Pilarcitos main.

Distribution.

San Francisco is a city of hills. The distribution of water under adequate pressure to all parts of the city is not, therefore, a simple matter. Some of the characteristic features of the distributing system as now in use are here briefly stated.

University Mound reservoir, capacity about 30 000 000 gal., located in the southeasterly portion of the city, at an elevation about 165 ft., receives the water from Crystal Springs reservoir with any added supply from Alameda Creek. The main conduit from this reservoir crosses Islais Creek on a trestle and supplies the low down-town section of San Francisco. The pumps at Black Point, which have a capacity of 5 500 000 gal. per day, draw upon this low-pressure system and serve the high-lying hilltops in the northern part of the city. Water is delivered by these pumps into the upper reservoir on Russian Hill and into the steel tanks on Clay Street hill and out on Presidio Heights. The Francisco Street reservoir, at elevation 140 ft., is at the end of a large main of the low-level system and serves admirably as a recipient of water during the night and a pressure equalizer during the day.

College Hill reservoir, in the south central part of San Francisco, receives the waters arriving in the San Andres main. The capacity of this reservoir is about 15 000 000 gal. Its elevation is 255 ft. It supplies a zone of very irregular outline next above the low-level area.

Lake Honda, located south of Golden Gate Park near the Almshouse tract, receives the waters of the Pilarcitos main. It has a capacity of 33 000 000 gal. Its elevation of 365 ft. gives it command of a region next above that served from the College Hill reservoir. The greater portion of the Western Addition is served from this receiving reservoir.

The highest district in the city now served with water is supplied through the Clarendon Heights pumps located at Seventeenth and Noe streets. The pumps have a capacity of 5 000 000 gal. per day. They can draw either upon the University Mound or the College Hill system. The pumped water is delivered into the Clarendon Heights tank, which is located on a spur of the Twin Peaks at an elevation of about 600 ft.

The gradual growth of San Francisco, and the need of keeping outlying districts, though sometimes sparsely populated, supplied with water, has led to the retention in use of much pipe of smaller diameter in many streets than would now be laid therein. The network of pipes now in use is not, therefore, fully up to the standard that would be prescribed for an entirely new system, particularly so long as water for extinguishing fires is supplied through the same mains which distribute water for other uses. Some idea of this fact results from a comparison of the pipes that would be required in a new distributing system (as planned in 1902) with the pipes now in use.

PIPES IN DISTRIBUTING SYSTEM, 1902.

Diameter of Pipe, Inches.	Water Pipes of the Spring Valley System.		Water Pipes of the Proposed Tuolumne System (including Specials).	
	Wrought Iron, Feet.	Cast Iron, Feet.	Wrought Iron, Feet.	Cast Iron, Feet.
Specials		16 000		
3		130 809		
4		344 321		81 700
6		570 983		170 230
8		621 900		1 868 910
10		9 912		312 190
12		226 278		785 080
15	850			
16		121 154		752 780
20		21 840		90 960
22	25 481	23 488		52 740
24		20 820		395 540
30	12 669	4 494		227 830
33	2 510			
36			12 650	
37½	12 254			
44	7 213			
48			47 940	

Before the fire in 1906 there were in San Francisco about 50 000 connections with the Spring Valley Water Company's pipes. This number was reduced to about 30,000 after the fire. It is now in the neighborhood of 40,000.

Aeration and Measures to Prevent Pollution.

The water delivered to San Francisco comes in large part from storage reservoirs, in which its appearance and quality are without doubt improved. But as these reservoirs are fed by streams that are turbid during their freshet stages, and as they are located at low altitudes, exposed to the hot summer sun, it has not been possible to keep them entirely free from minute algæ and other vegetable growth. The screening process to which the water is subjected, as explained, removes much of this objectionable matter and the quality of the water is further improved by aëration, which is effected by discharging it upon an elevated platform from which it drips in successive stages to lower platforms. The water of the Pilarcitos pipe line and that pumped from Lake Merced are thus aërated on Daly's hill near the point where the Pilarcitos line crosses the south boundary of the city; the San Andres water is aërated just before being delivered into College Hill reservoir.

The main reliance for preserving the wholesomeness of the water supply is placed by the water company upon the protection of the watersheds against pollution. Over 2 700 acres, 4.4 sq. miles, or more than one half of the area tributary to Lake Merced, is thus owned. About 28 of the 36 square miles of watershed in whole or in part tributary to the Peninsula reservoirs are owned by the water company. On Laguna, Calaveras, San Antonio, Valle and Hondo Creek of the Alameda Creek system, the area owned is close upon 25 000 acres. On those portions of the watersheds where sources of pollution were most to be feared, the police control and the restriction of human activities have been made easy and effective by this policy of land ownership. The Coast Range sources of supply now utilized, or noted as within reach of the Spring Valley Water Company, are, nevertheless, not ideal sources of water for domestic use. The collecting ground is not of the high snowcapped mountain type, but is of the low soil-covered mountain and foothill character. Much of it is brush covered. Animal life and a certain amount of human activity in the watersheds, the natural turbidity of most of the water and the presence in it at times of more or less organic matter all point to filtration as a proper treatment

for the improvement of the water. Some of it, in fact, may be considered as already receiving this treatment. The water that issues from the Pleasanton wells has passed long distances through gravel deposits and that of Suñol Valley as collected in the filter galleries issues clear and inviting.

Undeveloped Sources within Control of Spring Valley Company.

Among the properties owned by the Spring Valley Water Company which have not been developed there may be noted:

Calaveras Valley on Calaveras Creek. — This is a reservoir site to which there are directly tributary about 100 sq. miles of the region round about and to the north of Mt. Hamilton. To this area about 40 sq. miles more can be added by diverting Hondo Creek waters into the Calaveras Valley. The rainfall on the watersheds that are or can be made tributary to the Calaveras Valley is only about two thirds of the rainfall near the Peninsula reservoirs. The water production will, therefore, be less. It will in a year of normal rainfall probably be about 225 000 gal. per sq. mile per day. The total water supply that can be hoped for from this source is not, however, to be deduced directly from this unit quantity and the drainage area. It will depend in a measure upon the extent to which the Hondo Creek waters can be intercepted, and in a large measure upon the amount of water that will reach the reservoir site in wet years in excess of storage capacity. The dam site for the Calaveras Valley reservoir has been thoroughly explored by the engineers of the Spring Valley Water Company and so far as has been disclosed by them the results of the examination are satisfactory. A dam with a crest 187 ft. above the natural surface of the ground would, according to estimates made by Mr. T. R. Scowden, who investigated this matter for San Francisco in 1874, create a storage capacity of about 30 000 000 000 gal. The run-off from the watersheds directly and indirectly tributary to the Calaveras reservoir will, in seasons with the maximum fall of rain, be more than twice this amount.

San Antonio Creek. — San Antonio Creek is a tributary of Calaveras Creek. On this creek a short distance above the point where it enters the Suñol Valley is a reservoir site to which about 40 sq. miles of the low mountain region northeasterly from Mt. Hamilton are tributary. On this watershed the rainfall is somewhat less than on that of the Calaveras reservoir. The amount of water which flows through the reservoir site

in a year in which the rainfall is normal is equivalent to an average flow of about 5 000 000 gal. per day.

It is to be noted that both the dam at the Calaveras site and the dam at the San Antonio site will hold back water that now flows to the Suñol gravels. There is, therefore, a certain interrelation between the amount of water produced by the intercepting works in the Suñol Valley and the water impounded in the reservoirs. This is also true of the proposed water development by storage on the Arroyo Valle. This last-named creek enters the Livermore Valley from the south and much of its flow sinks before reaching Pleasanton. It is a feeder and perhaps the principal feeder of the artesian strata from which the Pleasanton wells obtain their supply.

On the Arroyo Valle the Spring Valley Water Company has secured a foothold. It owns or controls a reservoir site of moderate capacity. The watershed tributary to this reservoir site is about 130 sq. miles, and the normal rain upon this drainage basin may preliminarily be taken at about 24 in. per year. The amount of water which flows through the reservoir site in a year with normal rain should be about 18 700 000 gal. of water per day.

On the Niles cone, too, the water company has acquired lands. The Niles cone is a flat gravel deposit which spreads out, fanshaped, from the mouth of Niles Cañon southwesterly across the valley region east of San Francisco Bay. It is permeated by the waters of Alameda Creek. These waters are within reach of pumps, and their development may in time be justified. As the total area of the watershed tributary to the Niles Cañon is about 600 sq. miles, and the three reservoirs above enumerated intercept (though only in part) the run-off waters from 310 sq. miles, there will always be some water, at least in wet years, from the other 290 sq. miles, together with the wastage from the reservoirs, to replenish the water of the gravel beds in Livermore Valley, in the Suñol Valley and in the Niles cone.

It will be readily understood that the lack of data, particularly in so far as they relate to the dimensions of structures by means of which water is to be stored, capacities of reservoirs to be created and capacities of conduits for the utilization of the water or its transfer to other reservoirs, as well as more or less uncertainty relating to rainfall and run-off, would render useless any attempt to now make a final estimate of the water production of the various sub-elements of the Alameda Creek

system. The daily watershed production above noted for the several reservoirs in years of normal climatic conditions on tributaries of Alameda Creek are only a first indication of possibilities. They cannot be fully realized. Even in the case of the Calaveras reservoir, which has a very large capacity, the inflow from the tributary watershed (including Hondo Creek) may in a single year of maximum rainfall be enough, as already stated, to fill the reservoir twice. Some water being assumed in storage at the beginning of such a season, there will then be large wastage, of which perhaps only a small portion may become available by infiltration into the Suñol gravels and the Niles cone. The proportional wastage in occasional years on the San Antonio and on the Arroyo Valle will be still greater, because the storage is there relatively smaller.

However, to give some idea of the total possible water production on Alameda Creek in its entirety, it may be stated that the mean run-off indicated by drainage area and rainfall is estimated at about 90 000 000 gal. per day. If this amount of water, or whatever the exact figure for the Niles Cañon flow may be, were intercepted by adequate devices above Niles Cañon, there would be no water for the Niles cone. This total, therefore, represents the extreme water production of the Alameda Creek watershed, including all local water consumption for whatever purpose and the waste, if any, by surface or subsurface routes to the bay.

San Francisquito Creek is frequently referred to as available for increasing the water production on the peninsula by about 7 000 000 gal. per day. This is probably an overestimate. It is understood that the Leland Stanford, Jr., University has a right to the first 3 000 000 gal. per day. As the run-off, estimated from the rainfall and the watershed of 15 sq. miles, will average only about 6 500 000 gal., this source should not be credited with a possible production of more than 3 000 000 to 3 500 000 gal. per day. On this creek there has already been constructed at Searsville a concrete dam 90 ft. high, which is to be raised to a greater height at some future time.

Of the various ocean slope creeks on the peninsula only one, as explained, Pilarcitos Creek, is at present made tributary to the established works. But it is generally admitted that if it were necessary to do so, though at relatively large expense, some additional ocean slope water could be intercepted and turned through a tunnel to the bay side of the mountains and ultimately into the Crystal Springs reservoir. To accomplish

this a long conduit of large capacity would be requisite. The ocean slope creeks afford but scant opportunity for storage at elevations that would permit water to flow from the collecting reservoirs into the Crystal Springs reservoir. The interception of storm waters would, therefore, be restricted to the short periods in winter when the creeks are high. During the rest of the year the natural flow of the streams is small, consequently only a small percentage of the annual output of the stream is then available for interception. A special study of the features of a project for the utilization of the ocean slope waters would have to be made before a close estimate of the probable ultimate yield of these sources could be made. But some idea of possibilities may be gained from the following: It is claimed that about 65 sq. miles of ocean slope drainages could be made tributary to an intercepting conduit with its head at Pescadero Creek. The run-off from this area, on which normal rainfall is about 40 in. per year, should average about 37 000 000 gal. per day, of which, depending upon the character and magnitude of the intercepting works, more or less would flow through the conduit. It is not at all improbable that about one half of this water can be made available, perhaps 20 000 000 gal. per day.

It now becomes possible to combine the foregoing figures relating to additional water development from sources that are near at hand and that are in whole or in part controlled by the Spring Valley Water Company. But to do this certain arbitrary assumptions must be made and these must be understood to be subject to modification as more data relating to storage possibilities, conduit capacities, rainfall and run-off become available. Thus it seems reasonable to expect that the Calaveras reservoir will make available about 25 000 000 gal. per day of the 35 000 000 that should flow through or past the reservoir in Calaveras and Hondo creeks. San Antonio reservoir may bring within reach 4 000 000 out of an average of about 6 000 000 gal. per pay, and on the Arroyo Valle about 10 000 000 gal. should represent the average amount intercepted.

The total run-off from the Alameda Creek watershed has already been noted at about 90 000 000 gal. per day. If the above amounts are realized on the tributaries named there will still be an average flow of about 51 000 000 gal. per day to feed the Pleasanton wells, the Suñol gravels and the Niles cone. As this water will come down the creeks mainly in wet winters when the creeks flash up quickly, a considerable portion thereof will

in all probability flow on to the bay and be lost. Some of it will be required for local use in Livermore Valley and elsewhere. It does not, therefore, seem safe to assume as a possibility that more than one half of the amount named, or about 25 500 000 gal. per day, can be intercepted by the Pleasanton wells, in the Suñol gravels and on the Niles cone, for delivery in San Francisco.

The water production of Spring Valley Water Company sources as developed and at ultimate capacity may, therefore, be tentatively stated as follows:

Sources.	Developed Supply. Gallons per Day.	Ultimate Supply. (Approx.). Gallons per Day.
Peninsula Reservoirs:		
Pilarcitos		
San Andres		
Crystal Springs	18 000 000	18 000 000
Lake Merced	3 000 000	3 000 000
San Francisquito Creek		3 500 000
Pescadero, and other ocean slope creeks		20 000 000
Alameda Creek:		
Calaveras Reservoir		25 000 000
San Antonio Reservoir		4 000 000
Arroyo Valle Reservoir		10 000 000
Pleasanton wells, Suñol gravels, Niles cone	15 000 000	25 500 000
Total	36 000 000	109 000 000

The foregoing statement in relation to the possible extension of the water works to other Coast Range sources of water is made to show that the possible expansion of the Spring Valley Water Company's system is not inconsiderable. It may also be noted that arrangements could be made to draw, in case of emergency, upon the great artesian water supply known to be within reach at the southerly end of San Francisco bay. A line of wells near Alviso would be a desirable addition to any water works system, but a draft upon such wells would, if long continued, have more or less effect upon the yield of the other wells in the Santa Clara Valley, and this source should not, therefore, be looked upon as available for large quantities of water except in cases of emergency and for short time periods only.

If the city were the owner of the water works under the circumstances, as above explained, attending their possible expansion, it would seem that the first step to take would be to supplement the developed supply by adding a large amount of

Sièrra Nevada water. When this is accomplished the doubtful or least desirable sources now in use, such as Lake Merced, should, at least temporarily, go out of use. A time will then come when the works bringing to the city the mountain water will be taxed to their capacities. These works can then be added to and capacity increased until the limit of increase, indicated by the productiveness of the source, has been reached. This will be at a remote day, but when it comes recourse may still be had to the various additional nearby sources of water.

Supplemented by pure mountain water, the yield of the present sources of supply would be improved in quality. The peninsula reservoirs would be kept full of water or nearly so, and the Alameda gravels and Lake Merced would be called upon for water only when an emergency made this necessary.

The Tuolumne River Projected Development.

Although required, as city engineer, to plan water works with the Tuolumne River as the sole source of supply, the writer in his report on this project, and at other times, has pointed out that the needs of San Francisco would be best served by using the Tuolumne River sources in combination with the established water works system. No attempt has ever been made by him to belittle those advantages of the Spring Valley Water Works that are easily recognized in the nearness of its sources of supply to the place of use; in the reliability of the service rendered, due largely to the close proximity of some of its sources of supply to San Francisco and to works for safeguarding the service; in the large capacity of the storage reservoirs, which are close at hand, and in the fact that the service is an established one.

But the time is now at hand when a large addition to the water brought into San Francisco must be made, when it must be determined whether this addition shall be made by the Spring Valley Water Company or by the city; whether, in short, the water works that supply water to San Francisco are to be municipally owned or whether the established company should be allowed, as in the past, to expand its system by adding to it more water from Coast Range sources.

The writer's view that water consumption in San Francisco can be kept down to about 80. gal. per inhabitant is not shared by other engineers. Mr. Schussler, Mr. Stearns, Mr. Schuyler and others are of the opinion that the water consumption will increase much more rapidly than proportionally to population. They base their conclusions on the experience of

other large cities, notably of cities in the United States. Reasons for not accepting their conclusions have already been set forth. Be this as it may, the fact remains that San Francisco is a rapidly growing community, for which various forecasts relating to future population have been made, and that the growing city will demand more water from year to year.

The writer's figures relating to future population, as published in official reports, would probably have turned out to be underestimates if the city had not received the great setback resulting from the fire of 1906. They are given in the following table without correction for the loss of population in 1906, together with the estimates made by Mr. Schussler. It now seems probable that in ten to fifty years the actual population, unless increased suddenly by the addition of new territory, will lie somewhere between the figures noted in the table.

Population and Water Consumption Forecasts.

	Population.		Water Required, Gallons per Day.	
	Grunsky.	Schussler.	Grunsky.	Schussler.
1910.......	415 000	500 000	33 100 000	40 000 000
1920.......	490 000	650 000	39 200 000	55 000 000
1930.......	570 000	800 000	45 600 000	72 000 000
1940.......	650 000	950 000	52 000 000	90 000 000
1950.......	735 000	1 100 000	58 800 000	110 000 000

(Tuolumne) Quantity.

The quality of the water at the selected reservoir sites on Tuolumne River was investigated with satisfactory result. The question next to be answered related to the quantity that could be made available. On this point the writer, in his official reports, has been conservative. This question was treated throughout from the point of view that the Tuolumne River would be made the sole source of supply. The water production in a year of minimum rainfall was, therefore, used as a basis for the discussion of quantity that could be delivered, while the increase that would result from holding water over from one year to another in special storage reservoirs was not taken into account. Neither was any full discussion attempted of the amount of water development that would be possible by increasing storage at the selected sites by building higher dams. It was enough for the purpose of the reports on this subject to show that a development of water in large quantity was possible and that after the

needs of prior users on the stream were supplied there would be enough left to warrant the construction of the water works.

In the writer's official report on the Tuolumne River project it was shown that Lake Eleanor reservoir, if given a useful capacity of 12 000 000 000 gal., would be nearly twice filled in years of normal rainfall, and in years of minimum rainfall about three fourths by the run-off from the area directly tributary to the lake, and that the addition of other waters by interception, notably Cherry Creek, would bring to the reservoir in any year more water than required to fill the empty reservoir. Likewise it was shown that no year is to be expected in which the water flowing through Hetch Hetchy Valley will not be 20 to 25 per cent. greater than the proposed storage capacity of the reservoir.

The areas of the watersheds which are tributary to Hetch Hetchy Valley and to Lake Eleanor have been estimated at 452 and at 84 square miles respectively. The drainage basin of the Tuolumne River at La Grange, where the diverting dam of Turlock and Modesto irrigation districts is located, is 1 501 sq. miles. It follows, therefore, that there will be left in the river much of its natural flow entirely undisturbed by the works proposed for San Francisco.

To make a satisfactory estimate of the quantity of water that can be developed on the Tuolumne River for use in San Francisco more data are required than are now available. It is necessary in this case to know not only how much water per annum reaches the reservoir sites and the capacities of the reservoirs and conduits, but also to know the demands that will be made upon the river by other users of its waters. It is known that the river in the winter and spring months has a large flow, occasionally sending into San Joaquin Valley in 4 or 5 days as much water as would fill the proposed storage reservoirs. The retention of such storm waters in mountain reservoirs would admittedly be beneficial to all persons located on the river or using any of its waters. During the high stages of the river natural flow would supply all demands and there would be excess for storage. It is probable that the reservoirs would be drawn upon not more than 8 months in any year. Their proposed capacity, therefore, enables a first approximation to be made of the amount of water to be expected from this source. Estimated on this basis at least 170 000 000 gal. per day should be obtainable.

That this is a conservative estimate and will be materially

increased when more precise information is available appears from the following considerations:

The assumed minimum annual rainfall on the tributary watersheds will fill the reservoirs. This minimum is 18 in. per annum. It is in all probability too low, and if too low much more water will be available for storage than has been assumed, and larger reservoirs would be justified to equalize the river's flow.

No supplemental storage to equalize the flow, as between years of copious rain and years of light rainfall, has been assumed. Such additional storage is possible in the Hetch Hetchy Valley by constructing a higher dam and is possible in other sites of the Tuolumne basin. It is also obtainable near San Francisco, particularly if the Tuolumne project is made supplemental to the Spring Valley system.

The determination of the run-off in a year of light rainfall is, in other words, only a first safe approximation of the amount of water to be expected, and it is in this sense that the above estimate should be accepted.

(Tuolumne) Storage-Basins and Conduits.

The works by means of which it was proposed by the writer to make Tuolumne River water available in San Francisco may be briefly described as follows:

The granite gorge at the lower end of the Hetch Hetchy Valley is to be closed by a masonry dam rising to a height of 150 ft. above the valley floor. The gorge at the surface of the river has a width of 136 ft. The crest length of the dam, 150 ft. high, would be 400 ft. The dam would be arched upstream and surplus water would flow over its crest. Above the dam would be a bridge. The surface area of the reservoir would be about 1 180 acres. Its storage capacity would be 33 000 000-000 gal.

The additional storage at Lake Eleanor is to be secured whenever conditions make it desirable to regulate the flow of Tuolumne River still further than would be possible by a dam at Hetch Hetchy Valley alone. The Lake Eleanor dam would be located about 1¼ miles below the lake on a solid rock ledge. It would be about 75 ft. high, slightly arched upstream, and would have a length of 1 300 ft. The total amount of water impounded by it would be about 13 000 000 000 gal., of which about 12 000 000 000 gal. could be made available.

When still further storage is needed the first step to secure

it will be to raise the Hetch Hetchy dam. An added height of 50 ft. would about double the storage in Hetch Hetchy Valley. The higher dam would be quite feasible.

Except at times when the reservoirs are full and water is wasted over the tops of the dams, the outflow from the reservoirs would be under control. The outflow from the Hetch Hetchy reservoir would flow in the deep gorge of Tuolumne River about 16 miles from the point where it is discharged through the reservoir outlet works to a diversion point at or a short distance below the mouth of Jawbone Creek. A point about one mile below Jawbone Creek has been tentatively selected as the diversion point. Water from Lake Eleanor reservoir would also reach this point by flowing down Eleanor Creek to Cherry Creek and down Cherry Creek to the Tuolumne River.

It is to be assumed that at this point the river water will rarely, if ever, be turbid. The diversion will, therefore, probably, be practically continuous. Suitable provision for keeping drift out of the conduit and for sluicing out sand deposits will, however, be made. The water taken out of the river will be carried in canal and tunnel, with occasional inverted siphons (as across the cañon of the South Fork), about 28 miles to a mountain spur from which, in a distance less than 2 000 ft., a drop of 766 ft. is available for the generation of power. This is at Bear Gulch.

Below Bear Gulch the canal will be cut into the mountain slope on the south side of Tuolumne River at an elevation about 350 ft. above the water surface of the river. The conduit at Moccasin Creek will be an inverted siphon of iron pipes about a mile long. When Red Mountain Bar is reached Tuolumne River will be crossed, also in iron pipes forming an inverted siphon. The water discharged by this siphon on the right or northwesterly bank of Tuolumne River will flow a short distance, about 640 ft., in an open canal. It will then enter a tunnel 2 660 ft. long, will be piped across a depression 4 450 ft., will enter another tunnel 1 130 ft. long, will be piped across another depression, and will then enter a tunnel 11 430 ft. long that will discharge it into the watershed of Dry Creek. A short canal will carry it to a point from which it can be dropped 330 ft. to the elevation selected for the head of the pipes across the San Joaquin Valley.

Both the drop at Bear Gulch of 766 ft. and that at Dry Creek of 330 ft. are to be utilized to generate power which can

be transmitted electrically across San Joaquin Valley and there utilized to pump the water over the Livermore pass at Altamont. Suitable power installations are to be made for this purpose. It will not, however, be necessary to erect a power station at Dry Creek so long as only a part of the water arriving at Bear Gulch will be required for use in San Francisco. Power generation may thus, for many years, be confined to the single station.

The surplus water there used for power will be a part of that which would under any circumstances have been allowed to flow in the river to La Grange for the irrigation canals.

After passing the Dry Creek power station the water will be delivered into the San Joaquin Valley pipes from a small reservoir. Local run-off is to be excluded from this reservoir, and it will be equipped with adequate outlet structures to screen and control the water flowing into the pipes and to drain the reservoir when necessary. The water surface in this reservoir is to be at 567 ft. above city base.

Across the San Joaquin Valley, in a direction almost due west, the water will be carried 60.5 miles in riveted pipes 48 in. in diameter. Stanislaus River will be crossed on a bridge, a long stretch of land subject to occasional overflow will be crossed on a trestle and the San Joaquin River, which at certain seasons of the year is navigable, will be crossed in submerged pipes. The project as outlined made provision for two 48-in. pipes across the San Joaquin Valley. In case that the Tuolumne project is to supplement the Spring Valley system, only one pipe would at the outset be required, and this would perhaps be of some other diameter probably somewhat larger.

The San Joaquin Valley pipes will discharge into a receiving reservoir at the Altamont pumping station, and from this reservoir the water is to be pumped over Livermore Pass. The receiving reservoir will be at elevation 155 ft. and the Altamont reservoir at elevation 740 ft. above city base. Allowing for the friction in the force mains, the pressure at the pumps will be equivalent to a head of about 625 ft. The pumping plant is to be of high duty, arranged for operation with electrically transmitted power. Some steam power is to be held in reserve for use in emergency.

On the summit at Livermore Pass the water will be discharged into the Altamont reservoir, which is to have a capacity of about 200 000 000 gal. This reservoir is at the head of the long line of pipes in which the water will be carried into

and across Santa Clara Valley. The route of the conduit will be westerly through the Livermore Valley across a ridge of hills between Valle and Calaveras creeks, where there will be a tunnel 1 mile long, thence crossing the Calaveras Creek and over the ridge west of this creek into the Santa Clara Valley. At the point where Santa Clara Valley is reached a drop of 80 ft. is practicable. It may, upon further study, be found desirable to utilize all of this extra head in the conduit, thereby reducing the size of pipes somewhat. Under the project as outlined in the official report, here (as across the San Joaquin and Livermore valleys) two lines of 48-in. riveted iron pipe each with a capacity of 30 000 000 gal. will be requisite. The route of these pipes will be around the southerly end of San Francisco Bay and thence northwesterly and northerly to an entrance into San Francisco by way of Colma. The location of the main supply pipes within San Francisco will be on the westerly slope of the main peninsula ridge, at an elevation between 200 and 220 ft., to the Ocean House road; along this road a short distance, thence by tunnel to the easterly side of the ridge at about elevation 214 ft.

For a system of water works, with Tuolumne River as the sole source of supply, it would be necessary to provide storage facilities somewhere near San Francisco for at least a 30-day supply. Much more would be desirable, because the water works of a large city should be amply safeguarded. No large reservoir site in or near San Francisco has been discovered at sufficient altitude to permit delivery of water from it to San Francisco by gravity flow. The best site that has been discovered is located near Belmont. By means of a dam rising to a height of about 105 ft. above the present surface of the ground, water can there be impounded to the extent of 3 000 000 000 gal. — a 50-day supply when the water consumption of the city has reached 60 000 000 gal. per day. The water surface in this reservoir would be at elevation 177 ft. above city base, not high enough to flow over the divide near Colma.

The Belmont reservoir would be filled from the Tuolumne mains and the water there stored would in the case of an emergency be pumped into San Francisco through the northerly section of the main pipes. Under the project as outlined a pump capacity of 30 000 000 gal. per day was proposed for this point.

(Tuolumne) Distribution System.

There would be two receiving reservoirs in San Francisco,

one with a capacity of 100 000 000 gal. on the House of Refuge lot, at the intersection of San José and Ocean avenues, and another east of Mission Road, just south of Amazon Avenue. The arrangement of the discharge into the receiving reservoirs is to be such that the full volume of water reaching the city can be sent into either of them. The elevation of these reservoirs would be 196 ft.

The distributing system that would be necessary for the water arriving in the city as described was carefully studied. To maintain adequate pressure, and yet avoid excessive pressure in the pipes, it was found desirable to arrange the water distribution in 5 levels, of which the low level alone was to be served by gravity flow direct from the receiving reservoirs. All other levels were to be served from two pumping stations, one located in the block bounded by Seventeenth, Eighteenth, Diamond and Eureka streets, and the other located near the House of Refuge receiving reservoir.

On the low-level system there were to be three reservoirs and two tanks with a combined storage capacity of 26 912 000 gal.

On the second level there would be two reservoirs and two tanks with an aggregate storage capacity of 29 830 000 gal.

On the third level there would be one reservoir and seven tanks with an aggregate storage capacity of 3 233 000 gal.

On the fourth level the storage to be provided in three tanks would be 1 448 000 gal.

On the fifth level in two tanks storage to the amount of 1 300 000 gal. would be provided.

The combined storage capacity of all the reservoirs on the city distributing system, including the two receiving reservoirs, would be 218 343 000 gal.

It is not necessary to describe the distributing system in detail. This paper would become too long if this were attempted. The diagrams and general location maps further illustrate the salient features of the project. It should, however, be stated that the distributing system of reservoirs, pumping plants and interconnecting pipes of the Tuolumne River project were planned to meet fully the requirements of the city. On this subject the report of 1902 may be quoted: "At the special request of the Fire Department, the smallest pipes on main streets have been planned 8 in. in diameter. This is in some cases, perhaps, in excess of immediate requirements, but as the pipes laid would serve from 50 to 100 or more years, and the additional cost involved is small, it was thought advisable to

comply with this request. The smallest mains in streets of secondary rank, and where only one or two fire hydrants are to be served, are to have a diameter of 6 in."

The distributing system thus planned would have been superior to the pipe system and reservoirs now in service. However, in the report on the Tuolumne River project, in discussing the same as a project to supplement the established works, the writer says:

"The city distributing system [of the Spring Valley Water Company] would come into use without modification, except the placing of larger mains in some sections of the city to insure the best possible fire protection, and the construction of a number of new reservoirs and tanks and an improvement of the pumping facilities. It is thought that an expenditure of $1 000-000 in betterments of this kind would be at once justified if the Spring Valley Water Works were augmented by a supply from the Sierra Nevada, and that about $500 000 would cover the cost of the receiving reservoir at the House of Refuge lot, and its service mains."

(Tuolumne) Purity.

In the progress report already referred to, after quoting Col. G. H. Mendell's favorable opinion of the high mountains of the Sierra Nevada (3 000 or 4 000 ft. upward to the summit ridge) as a source of water for municipal use, the writer says:

"Further observations have confirmed this view, and from personal examinations of the drainage basins of the rivers descending these western slopes, from the Yuba southward to the Merced, it is to be added that in other respects some of these drainage basins are ideal drainage grounds for a city water supply. The snow which accumulates during the winter and is not all melted until midsummer performs the same function as storage reservoirs, equalizing the flow of the rivers. The severity of the climate and the ruggedness of the regions of high altitude in the Sierra Nevada render them uninhabitable, and, it might almost be said, inaccessible for the greater portion of the year. Great areas, particularly southward from the drainage basin of the Stanislaus River, have in the past been accessible for pasturage only to a very limited extent, and they are now still protected against occupancy by man by being made national parks and forest reserves. The high Sierra is a region of granites, slates and lava, much of it bare, not yet covered with soil. Over vast areas the recent action of glaciers is traceable.

"The polished striated surfaces of the granite still glisten in the sunshine. Hundreds of small lakes have been carved out of the original surface of the country by the glacial action, notably in the region which includes the headwaters of the

Stanislaus, Tuolumne and Merced rivers, and the other streams of the Sierra Nevada further to the south. Other lakes are formed, in part at least, by the terminal moraines of glaciers, which have been left as barriers across the original outlets of valleys . . . " Throughout the high mountain region, and particularly in those portions thereof which show marked glacial action, lakes, as already stated, are numerous. Some of these are of considerable size, among the best known being Blue Lakes, Lake Eleanor and Lake Tenaya. The water of these lakes is, almost without exception, of remarkable purity. A large number have been personally visited and no reason seems apparent why the water of those of the glaciated, uninhabited high mountain regions southward from Lake Tahoe should not be considered equal in quality or even preferable to the water of Lake Tahoe, around which there will always be more or less marginal land available for human occupancy and desirable as a summer resort."

The quality of the water obtainable from Tuolumne River may be judged from the analyses made by the city chemist, Mr. Frank T. Green, in 1903.

Two samples of water were taken in sterilized large bottles by a chemist, Mr. J. H. Gray, acting under the writer's direction, the one from Lake Eleanor on September 30, 1903, the other on the same day from Tuolumne River in Hetch Hetchy Valley. The river was at that time at a low stage. The sample from the lake, it was thought, might be regarded as typical of the water that would be held in the enlarged Eleanor reservoir and in the proposed Hetch Hetchy reservoir. The results of the analysis were favorable, as will be seen from the following, submitted by Mr. Green under date of November 7, 1903.

	Lake Eleanor. Parts in 100 000.	Tuolumne River. Parts in 100 000.
Total solids	1.4	3.0
Loss on ignition	0.4	0.4
Fixed residue	1.0	2.6
Chlorine as chlorides	0.198	0.357
Oxygen consumed	0.132	0.07
Nitrogen as albuminoid ammonia	0.006	0.005
In first 50 cu. cm.	55%	53%
In second 50 cu. cm.	37%	26%
In third 50 cu. cm.	8%	13%
In fourth 50 cu. cm.		8%
Nitrogen as free ammonia	0.004	0.0024
In first 50 cu. cm.	50%	77%
In second 50 cu. cm.	34%	18%
In third 50 cu. cm.	16%	8%
Nitrogen as nitrites	0.00003	0.00004
Nitrogen as nitrates	0.0024	0.0012

Quantitative (Acids and Bases).

PARTS IN 100 000.*

	Lake Eleanor.	Tuolumne River.
Total solids	1.40	3.00
Fixed residue	1.00	2.60
Silica, SiO_2	0.307	0.567
Magnesia, MgO	0.028	0.060
Iron and alumina, Fe_2O_3, Al_2O_3	0.017	0.057
Lime, CaO	0.127	0.377
Sulphur trioxide, SO_3	0.101	0.131
Sodium chloride, $NaCl$	0.327	0.590
Carbon dioxide and undetermined	0.093	0.818

Calculated into Salts.

PARTS IN 100 000.

Calcium sulphate, $CaSO_4$	0.1717	0.222
Calcium carbonate, $CaCO_3$	0.1014	0.509
Magnesium carbonate, $MgCO_3$	0.0588	0.126
Sodium chloride, $NaCl$	0.3270	0.590
Silica, SiO_2	0.3070	0.567
Iron and alumina, Fe_2O_3,Al_2O_3	0.0170	0.057
Undetermined	0.0171	0.529

It is reasonably certain that Tuolumne River at its high stages would show still less of total solids in solution.

The following analysis of a sample of Lake Tahoe water, taken on October 16, 1900, was made by Mr. J. H. Gray, acting under the writer's direction. It is noted for comparison and to show the general excellency of the waters originating in the high mountains of the Sierra Nevada.

Lake Tahoe Water.

PARTS IN 100 000.

Total solids	6.5
Loss on ignition	1.5
Fixed residue	5.0
Chlorine	0.142
Nitrogen as nitrites	None
Nitrogen as nitrates	Trace
Nitrogen as free ammonia	0.0006
Nitrogen as albuminoid ammonia	0.0034
In first 50 cu. cm	71%
In second 50 cu. cm	23%
In third 50 cu. cm	6%
Oxygen consumed	0 010
Bacteria at 100 yds. off shore per cubic centimeter	1
Bacteria at 200 yds. off shore per cubic centimeter	0
Bacteria at 300 yds. off shore per cubic centimeter	0
Bacteria at 500 yds. off shore per cubic centimeter	0

* One Liter, the quantity used for each estimation, except in case of sulphates, then 500 cu. cm.

The water for the bacteriological examination was taken at a later date. It was plated immediately upon being taken and the results noted are considered reliable.

A sample of water for bacteriological examination from near the lake outlet taken at the same time that the samples for chemical analysis were taken showed a few bacteria (60 per cubic centimeter are recorded, page 344, Appendix Municipal Reports of San Francisco, 1900–1901), but it is noted (on page 379) that the determination of the number of bacteria should be ignored because immediately after the samples were taken a light flaky substance was noticed in the water, and because a delay in transportation occurred, making the time two days before the samples reached the laboratory.

Analyses of the waters that were being furnished to San Francisco in 1900 and 1901 by the Spring Valley Water Works were also made. The results are published in the Municipal Reports of 1900–1901, Appendix page 353 *et seq.* Later analyses in large numbers have been made by the city chemist under direction of the board of health.

(Tuolumne) Cost.

In 1902 a cost estimate was made of water works with Tuolumne River as the sole source of supply. The capacity of the works, which were made the basis of the cost estimate, was 60 000 000 gal. per day. The money, to be raised by a bond issue, was estimated at $39 531 000. This includes $8 807 000 for a distributing system. Interest during construction was not included because no part of the interest on the bonds would be paid out of the construction fund resulting from the sale of bonds.

Six years have elapsed since the cost estimate was made. Since that time the country has been swept by a wave of prosperity attended by a material increase of prices of materials and of wages and this wave has been followed by a period of more or less business depression attended by falling prices of materials and by a lower wage scale. The cost estimate, therefore, needs some revision. This revision and a suitable adjustment of the works to altered requirements would be all the more necessary if the project is to be so modified that it will supplement the Spring Valley system.

The cost estimate of the Tuolumne River water supply project, made by the writer as city engineer, was based on surveys and examinations covering all parts of the project. The

reservoir contents were determined from contour lines surveyed by the United States Geological Survey. The dams at Lake Eleanor and across the Tuolumne River at the lower end of the Hetch Hetchy Valley were planned after the sites had been surveyed and examined in person. The route for the canal and tunnels and pipe lines was surveyed throughout. The distributing system in the city, including receiving and distributing reservoirs and pumping stations, was worked out in sufficient detail to show location and plans of proposed structures and the complete network of pipes required. The maps and diagrams that were prepared to illustrate the project and to accompany the report were 36 in number. They are enumerated in the letter transmitting the Tuolumne River report. This enumeration does not, however, include the plane table survey sheets, of which there were a large number showing the conduit route.

In the water rate cases still pending, the engineer experts of the Spring Valley Water Company call attention to the underestimate of the cost of the proposed Tuolumne River project. These experts all testify to the need of carrying the water from the proposed point of diversion from Tuolumne River, — in fact, from the mouth of Cherry Creek some miles further upstream, — to San Francisco in covered conduits. Reservoirs, notably the Hetch Hetchy itself, which is located in the mountains at an altitude of 3 600 ft., are referred to as exposed to the hot sun, and this is noted as detrimental to the water quality. These criticisms are made, first, to discredit the superior quality of the mountain water as delivered, and, second, to establish a high cost of works for purposes of comparison with the Spring Valley system.

Among the engineers who have thus declared it to be necessary to cover the proposed open canal are Mr. F. P. Stearns and Mr. Jas. D. Schuyler. Their testimony is best refuted by quotations from a report in which they both joined a few months later.

Mr. Stearns, testifying in 1905 relating to the open canal section of the Tuolumne project, says:

" In an unlined open canal on a steep hillside, as in this case, water would deteriorate in quality both by its exposure to the sun in the shallow canal and by opportunity afforded for the pollution of the water; some would be lost by filtration, and such a canal would be more liable to accidents and interruption than a tunnel. It would seem to me advisable, in view of the very great length and cost of the work, that this portion should be built wholly in tunnel, fully lined, so that the works would

be less liable to interruption and to the liability of pollution and deterioration of the water which I have spoken of."

Mr. Schuyler in the same connection says:

"I do not believe that the water would maintain its purity after it left the headworks unless the scheme as outlined by him were to be materially changed and the water carried throughout in closed conduits. The proposition of carrying the water for 27 or 28 miles in open ditches along the mountain sides is one which must necessarily lead to constant pollution of the supply, not only from matter picked up from the bed and banks of the canal as it passes along, but it would be exposed to the action of the sun throughout that distance and subjected to the pollution from the drainage of the pastures through which it passed and subject to pollution from the wash of the mountain sides in storms and also from landslides from the mountains; the blowing of dust and leaves and other matter borne by the winds and deposited in the canal would further add to the pollution of the water."

Most of this open canal is to be along steep hillside. The following extracts are from the city engineer's report of 1902:

"The bottom width of the canal will be 9 ft.; the proposed depth of water 5 ft." "Rain water accumulating on the hill-sides above the canal is to be intercepted by a proper system of small ditches which will lead the water into ravines for which a crossing over or under the canal will be provided in each case as may be best adapted to local conditions."

After flowing down the Tuolumne River some 16 miles, and then in conduits, of which about 28 miles are of the uncovered type, the water will pass through two small reservoirs at the head of the Dry Creek power station, through a small reservoir at the head of the San Joaquin Valley siphon, through a small reservoir at the Altamont pumping station, through a reservoir having a capacity of 206 000 000 gal. at Altamont summit, besides 152 miles of tunnel and pipe, and if it should be thought desirable, can be made to flow through the proposed Belmont reservoir whose capacity is estimated at 3 000 000 000 gal., though this would involve some additional pumping.

With these facts in mind Messrs. Stearns and Schuyler may be again quoted. They joined with Mr. John R. Freeman, in a report dated December 22, 1906, on the project now accepted of supplying Owens River water to Los Angeles through a conduit 231 miles long. They say in this report:

"Our examination of the streams in the Owens Valley showed that the creeks coming from the Sierras furnished water which is clear, colorless and attractive; the water in the river,

being made up of the combined flow of these creeks, is of similar character, but has a slight turbidity and stain, owing apparently to drainage from the marshes in Long Valley and to other return water from the canals and irrigated lands. This feature would make the water somewhat objectionable if it were to flow directly from the river into the city pipes, and [but] it has little or no significance in the present instance where the water, after being taken from the river, is to be held for a long time in a large storage reservoir where the mineral particles which produce the turbidity will have time to settle. The long period of storage in the reservoir will also be an important safeguard against the transmission of disease germs should any enter the water of the river, because it has been found, both by experiment and experience, that disease germs are all, or nearly all, destroyed where the water is held sufficiently long in reservoirs."

The Los Angeles conduit, as recommended by the engineers above named, will be an open canal for 20 miles in Owens Valley; thence, still in this valley, for 40 miles it will be an open canal lined on bottom and sides with masonry laid in Portland cement. The next 15 miles of the conduit are also to be of the open type lined with masonry. In the following 24.5 miles there will be a reservoir of tunnels, siphon pipes and sections of bench conduit along mountain sides, the latter covered at the outset with reinforced concrete. Then come 20 miles of open, lined canal of easy excavation, with less than 4 000 ft. of steel flumes and pipes crossing dry wastes. All of the next 21.5 miles of the conduit will be under cover. The canal then emerges upon the smooth plains of Antelope Valley and will be lined, but without cover, for 64.5 miles. This stretch of the conduit is followed by a tunnel nearly 5 miles long to San Francisquito Cañon. The water is to flow down this cañon 11 miles until its use for power development becomes sufficiently important to justify the substitution of an artificial conduit. From San Francisquito Cañon to the head of the San Fernando Valley the water will be carried 15.18 miles in tunnels, siphons and covered canal.

Of the 164.5 miles of the lined section of the Los Angeles aqueduct, 19.8 miles are to be put under cover. The rest of the lined sections, 144.7 miles, are to be left open for the first five years of operation. The 22.2 miles of unlined canal are to remain open permanently, and the 11 miles of natural water course for an indefinite period, to say nothing of the flow of the water for many miles in Owens River above the proposed point of diversion.

The consulting engineers say of this project: "We find the project admirable in conception and outline, and full of promise for the continued prosperity of the city of Los Angeles."

Compared with Owens River the Tuolumne River is a far more desirable source of supply. Are not, therefore, the same words of praise applicable to the Tuolumne River project, in so far as the source of supply and the compared features of the project are concerned?

It is not necessary to notice other criticisms of the Tuolumne River water supply project by the engineer experts who testified for the Spring Valley Water Company. These, particularly such as those relating to the city engineer's failure to include in his cost estimate interest during the construction of the works, must be assumed to have originated in a desire to show a probable high cost for any system of water works independent of the Spring Valley system, in order that any weight given to a comparison with the cost of bringing in other water may be in favor of a high valuation of the Spring Valley Water Company's works. The matter of interest during construction is referred to in the city engineer's report, but was not included in the cost estimate to be used as a basis for a bond issue, because, as already stated, it was not proposed to make it a part of the bond issue. It is admittedly an expense connected with water works construction, but in the case of a municipality the fund out of which to pay it originates in the tax levy and is not a part of the fund resulting from sale of bonds as is usually the case when private corporations proceed with construction of works under a bond issue. Its omission from a cost estimate which was to serve as a basis for a municipal bond issue was not, therefore, an oversight.

Succinct Statement of Conclusions.

In weighing the merits of sources of water for the supply of San Francisco particular attention must be given to the following points:

The quality of the water.

The quantity of water that can be made available.

The reliability of the service.

The cost.

The main consideration is quality. The water supplied to a municipality must be pure and wholesome. It should be above suspicion. The best water within reach of San Francisco, in the light of all the information now available, is the water of the high Sierras. In the Sierra Nevada Mountains there are great areas of uninhabitable territory. Regions are there to be found to which human activities are not likely to be attracted,

and of these, many, by inclusion in national forest reservations and parks, will receive federal protection against invasion by any undesirable activity. These regions are, in part at least, of the bare granite type at high altitude. A careful study and exploration of these regions from Yuba River southward to the Merced River has led to the selection of watersheds on the head-waters of the Tuolumne River as the most desirable producing ground for water for San Francisco. Some of the facts that compel this conclusion may be briefly reviewed. Not one of the Sierra Nevada rivers, except Feather River, has a summer flow which would be adequate to meet the requirements of San Francisco in the matter of sufficiency of supply. But Feather River is out of consideration by reason of the remoteness of this source, the disadvantage of a conduit route that would cross the straits of Carquinez and the Bay of San Francisco, and the unfavorable collecting ground of the water, the vast extent and accessibility of which would render it impossible to exclude human habitations.

Water storage may, therefore, be set down as a requisite feature of any Sierra Nevada water project.

This having been determined, it is natural that the first thought should be of Lake Tahoe as an ideal source of water. No fault can be found with the quality of the water in the lake, which has a surface area of 250 sq. miles and is fed by the run-off from 250 sq. miles of high surrounding mountains. The mean annual outflow from the lake, through Truckee River, is equal to a layer of water 17 in. deep over the lake surface. This would be adequate for a population of about 2 000 000 people. Moreover, this water production could be increased somewhat by adding the water of Rubicon Creek, making an inter-connection between a small reservoir on Rubicon Creek and the lake by tunnel, in which water would flow into or out of the lake according to whether the creek were producing more or less water than conduit capacity to the city. But there are riparian rights around Lake Tahoe and improved properties on the lake shore, there are acquired rights to the flow of Truckee River for various purposes, and, moreover, full use is to be made of the entire stream flow in Nevada for irrigation. The superior use of the water for a municipal supply might be difficult to establish, particularly as the lake, and the watershed tributary to the lake, lie in two states and the flow from the lake is into the neighboring state, Nevada. So long as other adequate sources of supply in the Sierra Nevada are available, Lake Tahoe may, therefore, be dismissed from consideration.

Yuba River has received due consideration in the water supply investigation, more perhaps, than this river deserved. The same objection to location applies as in the case of Feather River. The water would be under suspicion of contamination and should be filtered before use. As in the case of a Feather River project, the crossing of the Bay of San Francisco is a feature that weighs heavily against the project.

American River comes under consideration on the same basis as the remaining Sierra Nevada streams. Its low water flow is already appropriated and in use for various purposes. Water to be made available on this stream must be impounded in reservoirs. Sites for large reservoirs, located so that they can be filled, have not been found in the high mountains. Long conduits of large capacity to low mountain basins, where local undesirable run-off complicates the problem, become features of the various American River projects. The high mountain area that belongs in the class that can be permanently preserved in an uninhabited condition is relatively small. This river, therefore, is less attractive than the Tuolumne, to which these objections relating to storage facilities and protection of watersheds do not apply.

Cosumnes River has, properly speaking, no high mountain watersheds.

Mokelumne River, under coöperation of water power companies, which control the situation, can be made available, but storage will be scattered in a large number of relatively small reservoirs and there will be much human activity in some of the areas tributary to the storage sites. It offers no such cleancut and attractive project as that outlined for the Tuolumne River.

On the Stanislaus River there are fair opportunities for storing water, but they are scattered and are, in part at least, already in use to supply water for power and other useful purposes. There is no place known on this stream where there is any approximation to the advantages offered by such a site as Hetch Hetchy Valley on the Tuolumne River.

In the case of Tuolumne River, as has been pointed out, exceptional facilities exist for storing water. Two sites were selected for the city of San Francisco. Both of these, and the tributary watersheds, are within a national forest reservation. Both are high enough in the mountains to exclude from tributary watersheds the undesirable lower lying mountain slopes. Their combined storage capacity, as originally planned, is about 45 000 000 000 gal. of water. This can be doubled by making

the dams higher. Where the river below these dams will carry the water to a point of diversion, the river lies in a deep cañon and its accessions are from small timbered mountain areas. Should it ever become desirable to exclude parts of these watersheds below the main reservoirs, this can be done by extending the headworks farther upstream. The fact that the divide between the main fork of the Tuolumne and the South Fork above the selected point of diversion lies very close to the main stream is a favorable feature; there will probably never be any south side run-off, except local hillside waters, to be excluded. On the north side of the main stream, Cherry Creek drains a region which is throughout acceptable as a tributary watershed. The only other stream of note coming in from the north is Jawbone Creek, on which, in the course of time, lumber interests may concentrate sufficient population, for a time at least, to make its exclusion desirable. A short extension of the canal upstream (about 1½ miles) would accomplish this.

The route for a conduit to bring the water from Tuolumne River to San Francisco is practicable and has, as stated, been surveyed. It includes a very long pipe line, but this, as is well known, is a necessary feature of any project for a water supply from the Sierra Nevada.

San Francisco has now advanced to the point where she controls storage sites in which abundant storm water from high mountain watersheds may be impounded to meet the needs of the growing city for many years. The secured source of supply can be used to supplement the Spring Valley system, or the water can be brought to the city in independent water works.

The city must now determine whether to adopt any or none of the following methods of procedure:

1. Continue as at present, water to be supplied by the Spring Valley Water Company at a fair compensation, and the works to be expanded to other sources as the needs of the city demand.

2. Construct an independent system of works with the Tuolumne River as a source of supply.

3. Acquire by purchase the established water works and add thereto, as a first enlargement, water from Tuolumne River.

The disadvantages of the first course of action have been made plain by experience. It will continue to involve the city in an annual wrangle with the water company concerning rates. The water company will, as in the past, find it difficult to extend its works as rapidly as good judgment would indicate

to be desirable. The probability will be that other near-at-hand sources of supply will be added before the works will be extended to any Sierra Nevada source.

If the city constructs a municipal system of water works as an opposition plant to the established works, the outcome will be that the value of most of the properties of the Spring Valley Water Company will be destroyed. This is particularly true of such portions of the works as cannot be used for other purposes than the supply of water to San Francisco. Operation by the company in opposition to the municipality is entirely out of the question. The rate payers will quickly learn that what they do not pay to the city in water rates must be paid in taxes. The private company could not name rates low enough to hold consumers, particularly when quality of water is considered. But the construction of a system entirely apart from the old has its disadvantages. The pipe system in the city streets would have to be duplicated, and some 50 000 house connections would have to be made at large expense to the property owners. The construction of a new system of pipes extending along every street would do no small injury to street pavements. Should the company desire to save any pipe by removal from the ground this might mean a duplication of much of the trenching. There would not be as much nearby storage as desirable.

Now that the city is ready to move in the matter of acquiring a system of water works, the only one of the three courses above enumerated that seems advisable lies along lines indicated in No. 3. The city needs certain things which the Spring Valley Water Company has, and it needs some of them most decidedly.

The city needs the distributing system of the water company, pumps, reservoirs, tanks and pipes without reservation. The city needs the peninsula storage system, Pilarcitos, San Andres and Crystal Springs reservoirs and watersheds. The city needs the pipe lines from these reservoirs to the city and the receiving reservoirs. The city needs Lake Merced as an emergency source of water, and it needs the Merced lands for park purposes. The city needs all of the properties of the water company, particularly if it should be found desirable to unite with other municipalities in the control of all nearby sources of water, and in the addition of a supply from the Sierra Nevada.

The city, if it become the owner of the water company properties, can continue the operation of the water works and

make suitable provision for the increasing demand for water during the time the Sierra Nevada works are under construction.

If the city, on the other hand, enters upon the construction of independent water works, it must be expected that the Spring Valley Water Company will curtail expenditures as much as possible, refraining particularly from new construction, and as a result there may be some years before the new works come into service in which the water supply will prove deficient.

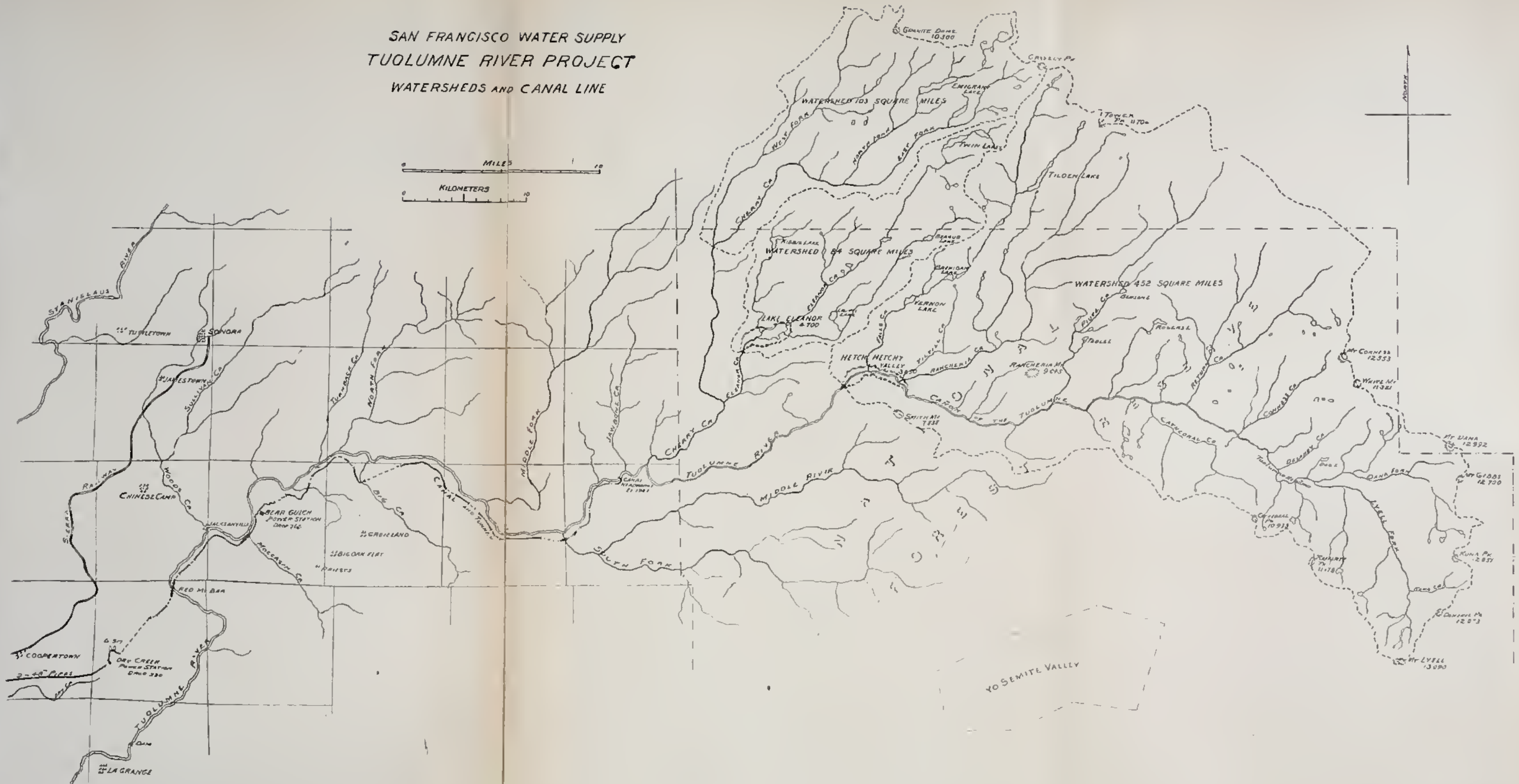
In case that the course, which has been pointed out to be the natural one, be followed, the first step to be taken will be to reach an agreement with the Spring Valley Water Company concerning the price at which its properties will be sold to the city. It will then be possible to outline a water supply project based upon the works as now in service, supplemented by a water supply of prime quality from the Tuolumne River, developed at the points where the city has already acquired rights of storage.

Again quoting from the writer's report on available sources of water, dated November 24, 1902:

> " Expense, so long as the same is within reason and not a burden upon the community, should not be spared in obtaining the best water that may be had."

There should be no hesitation, first, in acquiring the present water works, if this may be done at a fair price, and second, in reaching out to Hetch Hetchy Valley and Lake Eleanor for an additional supply.

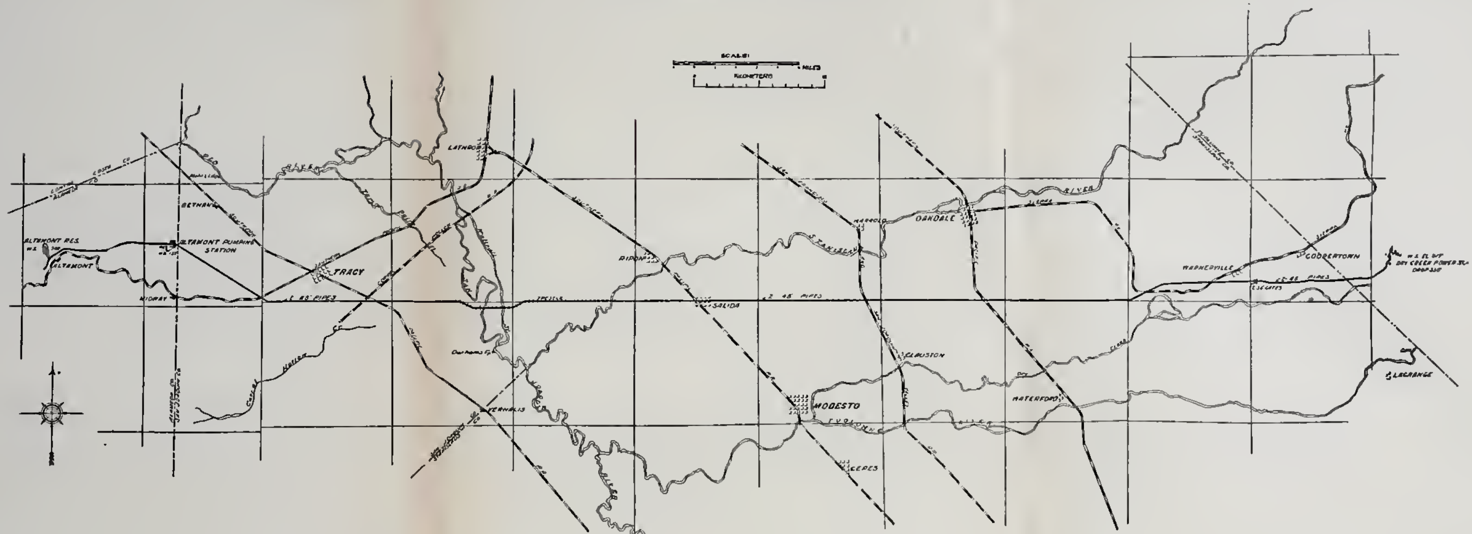
[NOTE. Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by December 15, 1908, for publication in a subsequent number of the JOURNAL.]

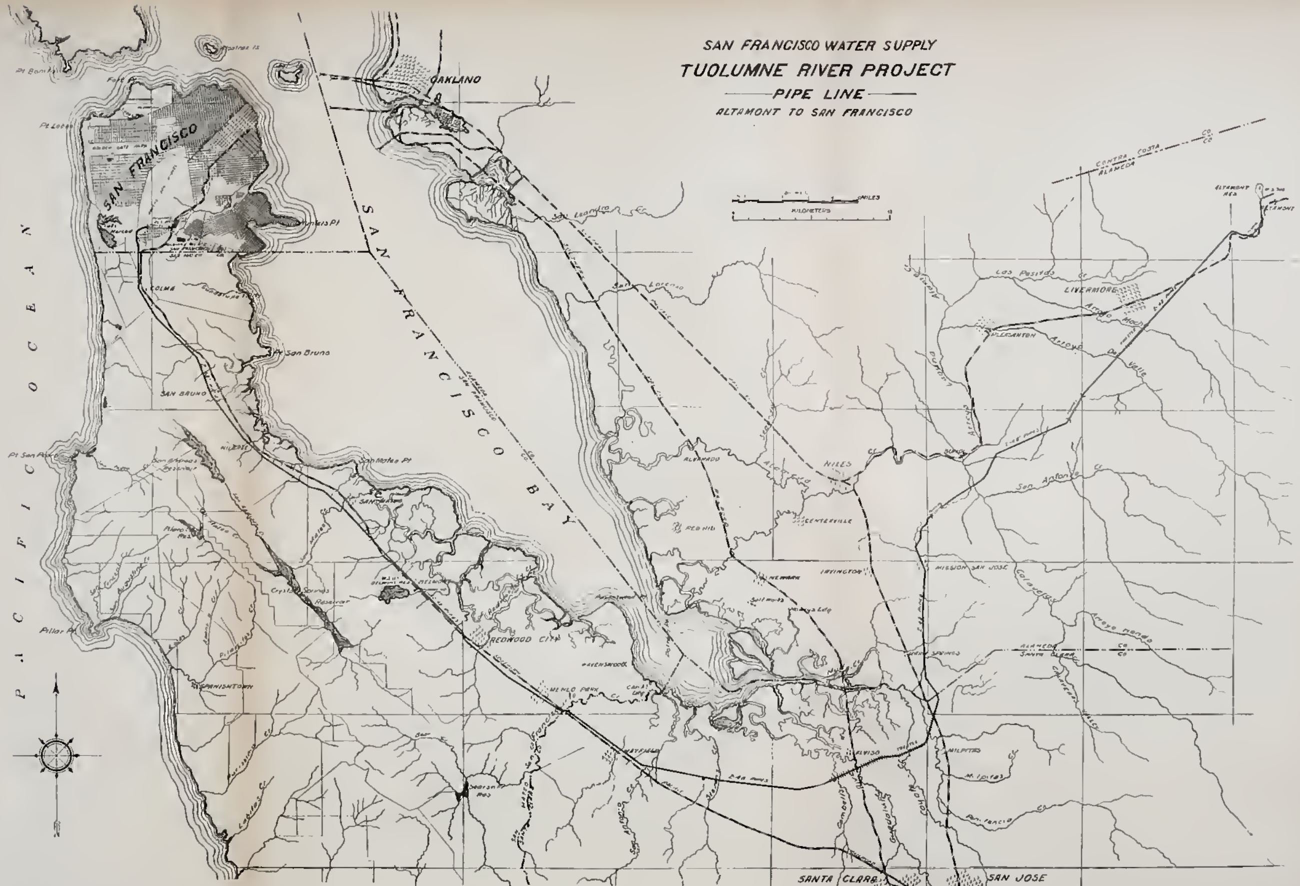

SAN FRANCISCO WATER SUPPLY
TUOLUMNE RIVER PROJECT
WATERSHEDS AND CANAL LINE
MILES
KILOMETERS
NORTH
WATERSHED 103 SQUARE MILES
WATERSHED 84 SQUARE MILES
WATERSHED 452 SQUARE MILES
STANISLAUS RIVER
SONORA
JAMESTOWN
SULLIVAN CR.
CHINESE CAMP
WOODS CR.
SIERRA RAILWAY
JACKSONVILLE
BEAR GULCH POWER STATION
MOCCASIN CR.
RED MT. BAR
COOPERTOWN
DRY CREEK POWER STATION
TUOLUMNE RIVER
LA GRANGE
GROVELAND
BIG OAK FLAT
NORTH FORK
MIDDLE FORK
CANAL AND TUNNEL
TUOLUMNE RIVER
MIDDLE RIVER
SOUTH FORK
CHERRY CR.
ELEANOR CR.
LAKE ELEANOR
HETCH HETCHY VALLEY
RANCHERIA MT.
CANYON OF THE TUOLUMNE
CATHEDRAL CR.
LYELL FORK
DANA FORK
TILDEN LAKE
TWIN LAKES
EMIGRANT LAKE
WEST FORK
EAST FORK
VERNON LAKE
TOWER PK.
GRANITE DOME 10,300
MT. CONNESS 12,553
MT. DANA 12,992
MT. LYELL 13,090
YOSEMITE VALLEY

SAN FRANCISCO WATER SUPPLY

TUOLUMNE RIVER PROJECT

PIPE LINE ACROSS SAN JOAQUIN VALLEY




SAN FRANCISCO WATER SUPPLY
TUOLUMNE RIVER PROJECT
PIPE LINE
ALTAMONT TO SAN FRANCISCO
SAN FRANCISCO
OAKLAND
SAN FRANCISCO BAY
PACIFIC OCEAN
LIVERMORE
PLEASANTON
NILES
SANTA CLARA
SAN JOSE
REDWOOD CITY
MENLO PARK
MAYFIELD
CENTERVILLE
IRVINGTON
MISSION SAN JOSE
ALVARADO
SAN BRUNO
COLMA
SPANISHTOWN
MILPITAS
ALVISO
NEWARK
Pt San Bruno
San Mateo Pt
Pt San Pedro
Pillar Pt
Crystal Springs Reservoir
Pilarcitos Res
San Andreas Reservoir
Los Positas Cr
San Leandro Cr
San Lorenzo
San Antonio Cr
Arroyo Valle
Calaveras
Alameda Cr
Searsville Res
CONTRA COSTA
ALAMEDA
SANTA CLARA

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PRESSURE FLUCTUATIONS IN TURBINE PIPE LINES.

BY PROF. A. BUDAU, ENGINEER, VIENNA, AUSTRIA.

[Translated from the German and partly read by Heinrich Homberger, Member of the Technical Society of the Pacific Coast, before the Society, March 20, 1908.]

THE progress in utilization of water power frequently compels the engineer to transfer his work from the inhabited valleys to rough mountain regions where, of the two factors of hydraulic energy, viz., head and quantity of water, at least the former is available in abundance.

The utilization of water power with high head, however, offers some difficulties. To obtain a high head, most frequently a long ditch is required whose construction is made difficult by unfavorable topographical conditions and obstructions to transportation. Next to this, in most cases, comes a very long pipe line which forms a very disagreeable link in the complicated mechanism of an hydraulic power plant, because it not only means an increase of first cost of the plant, but also causes complications of operation.

Against freezing of the pipe, covering of same is only a scant protection. During the time of severe cold weather, water has to run through the pipes continuously; otherwise they will freeze, notwithstanding the covering; but even during the warm seasons a pipe line can cause difficulties if, as is always the case in these days, a very accurate speed regulation of the turbines is required.

The modern turbine governors open and close very rapidly. Ten years ago governors were not an exception which, in case of

complete drop of load, happening, for instance, as a result of a short circuit in the electric net, shut the turbine off in twelve to thirteen seconds; but the time of closing has been continuously reduced, especially since the so-called hydraulic governors have been adopted, which have stored energy available, and to-day, a closing time of two seconds for turbines of many thousands of horse-power cannot yet be taken as the lowest limit.

It is impossible to rapidly stop the flow of a large quantity of water offhand, and certain precautions have to be taken. It goes without saying that these precautions have to be most careful and most complete if the water is conveyed to the turbine in a long pipe line.

The discussion of such devices, and some theoretical investigations referring to same which a practicing engineer, on account of the absence of any guiding material in literature, must carry out to satisfy the responsibility thrust upon him; further, some experiences with long pipe lines, will constitute the contents of this paper.

If a certain quantity of water Q flows through a pipe line of the cross section F, the water in this latter will obtain a certain velocity v which can be calculated from the formula $v = Q : F$, if the quantity Q of water is known which flows through the pipe in a second. If the water is conveyed through the pipe line to a turbine, and H is the head from the head water level to the distributer of the turbine, immediately in front of the turbine a water pressure will prevail which is equal to $H - \frac{v^2}{2g} - \frac{\xi v^2}{2g}$, wherein ξ represents the coefficient of the pipe friction and g the acceleration of gravity. If now, while the water is flowing, its discharge from the distributer is suddenly stopped, a great rise of pressure will take place, especially at the lower end of the pipe line, and unless the pipes are elastic, their rupture will necessarily follow.

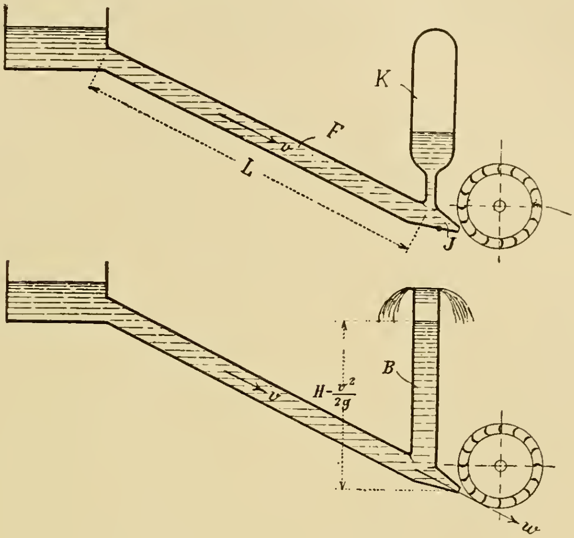
The water flowing in the pipe with the velocity v contains the energy A which cannot suddenly be destroyed and must necessarily express itself in deformations of the pipes. This energy, if L represents the length of the pipe line and F its cross section, expresses itself:

$$A = \frac{F \times L \times \gamma}{g} \quad \frac{v^2}{2} \qquad \text{I}$$

wherein γ represents the specific gravity of the water.

This rise of pressure, which, if occurring with considerable force, is feared in water mains as so-called hammer, one has

endeavored to reduce in turbine pipe lines by installing at the lower end of the pipe line an air chamber (Fig. 4) or a standpipe



FIGS. 4 AND 5.

B, also called free air pipe (Fig. 5), whereby the energy of the water flowing in the pipe line was to be given an outlet, compressing the air in the air chamber or lifting the water in the standpipe. Also safety valves have been applied.

There are, however, and especially in the most modern plants, by-passes or synchronous gates, devices which are operated simultaneously with the gate mechanism of the turbine so as to give to the water, which is held back when the turbine distributer is closed, an outlet into the tail water.

The writer advised such arrangements twelve years ago in a paper published in 1893 in the *Schweizerische Bauzeitung*. In the meantime, also, machines have been built where the non-utilized water passes through the distributer of the turbine, and such turbines, with combined distributer and free passage regulation, are designated as free passage turbines.

Standpipes are used under heads up to 100 ft., and economically only then if the topographical conditions are otherwise favorable. Air chambers have been frequently installed in former years; nowadays, however, they are not used any longer. Under the high pressure the water absorbs the air which is above it, and continuous refilling with air by means of specially provided compressors was found necessary, which soon became

cumbersome to the operators. One also hears, in some cases, that the governors operate better if the air chamber does not contain any air at all and is a water chamber only; and that the shocks of the water are not so bad as to cause any damage to the pipe, etc.

This, indeed, is logically correct, and it can be easily proved that air chambers themselves can become the cause of increasing periodical oscillations of the speed governors.

In a U-shaped bent tube (Fig. 1), let water be up to height H, which, of course, is equal in both legs. By some cause the water is brought into oscillation, and it will rise above the line ab in either leg alternatively, and fall below H. These oscillations of the water level in the two legs of the tube will last quite a while; in fact, they would not stop at all if there was no friction at the walls of the tube and between the particles of water themselves. The elevation of the center of gravity S of the water cylinder of the cross section F and the length h, or, in other words, the length h multiplied by the weight of the water cylinder, $F \times h \times \gamma$, gives the amount of energy which is contained in these oscillations and which also had to be contributed to the water to bring it into oscillation.

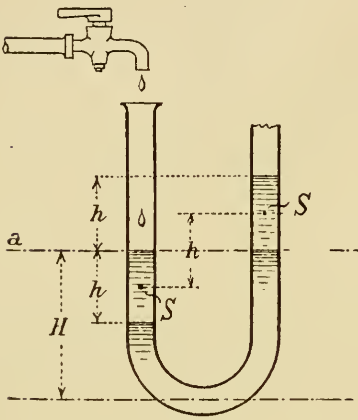


Fig. 1.

If now, while the water level is going down, a drop of water is allowed to fall into it, the height of oscillation h will be increased a small amount, and if frequently at the correct moment a drop falls upon the oscillating fluid, the oscillations of the water will increase until an overflow of water over the edge of the tube takes place.

The same will occur if one of the two legs of the tube is closed on top or if an air cushion is located above one of the water levels (Fig. 2), only in this case the oscillations h will be smaller and will only reach a certain maximum value, since the reaction upon the water level in the closed leg of the tube increases with increasing rise.

Also a moving water column can be brought into increasing

oscillations by continuous small impulses if it is connected with an air chamber.

Through the left leg of the U-shaped tube (Fig. 3), water is supposed to flow with a velocity v, discharging through a cock J.

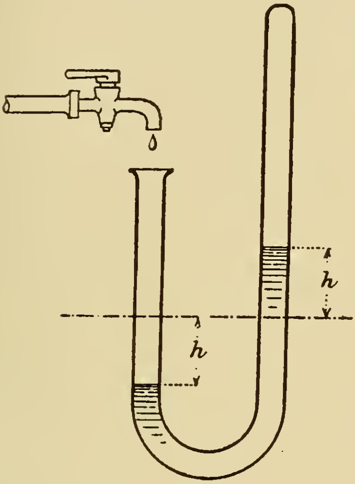


FIG. 2.

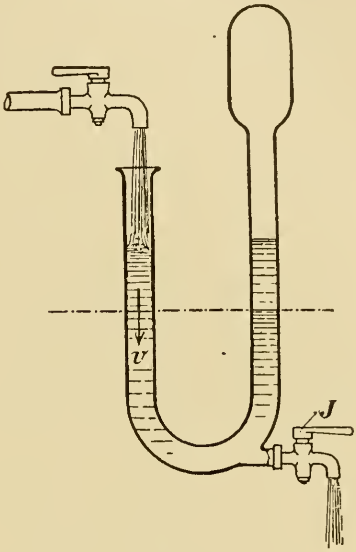


FIG. 3.

If now this cock is suddenly closed, a rise of pressure takes place which will cause a compression of the volume of air in the right closed leg of the tube, and the fluid, the flow of which is stopped, will be brought into oscillation exactly as in the previous case. If the cock J is not entirely but only partially closed, this will also cause an impulse to oscillate. There will also be oscillations which will be smaller than if the cock had been closed entirely, but which will last until the impulses of the particles of fluid against each other, and especially against the ones newly entering in the left leg of the tube, and further, the friction of the water on the walls of the tube, have used up the respective amount of energy.

If, for instance, the cock is only half open and be closed a certain amount every time when the water in the right leg rises, and then opened again, the oscillations can be raised to a maximum amount, the analytical calculation of which is not simple; but it will occur if the cock is alternately entirely opened and entirely closed.

Considering a high-pressure turbine provided with air

chamber and governor (Fig. 4), one can see immediately its analogy with the arrangement shown in Fig. 3. The regulating apparatus of the turbine has taken the place of the cock J in Fig. 3; the retardation of the flow in that moment at which the pressure rises, viz., when the water enters the air chamber K, is accomplished with the greatest accuracy by the speed governor. If, from any cause,— for instance, on account of shutting of a by-pass in the pipe line, — a rise of pressure occurs at its lower end, the governor of the turbine running under a constant load will be forced to somewhat reduce the amount of water entering the turbine; since the pressure rise, on account of the shutting, would have as a result an increased flow of water from the supply apparatus, therefore a larger amount of water supplied to the turbine; this would result in a speeding up of the turbine. The now following return wave will cause a drop in water pressure, the output of the turbine will be reduced, the governor will open and again close at the next pressure rise, and it can easily be seen that under these conditions the governor can increase the oscillations in the water column up to a certain maximum value.

Such experiences with air chambers have been had at many places and it is surprising that so far nothing about them has gained publicity.

The above investigation also shows that the oscillations will decrease the quicker, the larger the amount of water flowing through the pipe line, because the newly entering water, on account of its inertia, will counteract the oscillations and, therefore, is a very powerful factor in damping the water fluctuations.

This also explains the fact, which is very little known, that one can steady the governor which has become uneasy on account of water oscillations in the pipe line by opening a by-pass and giving the water in the pipe line a higher velocity. Experience also shows that simultaneous oscillations of the governor and of the water in the pipe line more readily happen when turbines utilize small quantities of water, viz., in cases where the velocity of the water in the pipe line is low.

In this respect standpipes, which have been frequently used in America, are better than air chambers. At a sudden complete or partial closing of the supply apparatus of the turbine (Fig. 5), the water level of the standpipe B will rise on account of the rise of pressure, and part of the water Q' will overflow the edge of the standpipe. The energy of oscillation, as a result, will be decreased in accordance with the ratio $\frac{Q'}{Q-Q'}$, if Q represents the

quantity of water flowing in the entire pipe line. The return wave must, therefore, be necessarily much smaller since the water at each following forward wave loses some of its energy on account of the water overflowing the edge of the standpipe. This circumstance, and the damping action of the water newly entering the pipe line, which changes energy of oscillation into eddies and friction, just as with air chambers, brings the oscillations very quickly to a stand-still, even if the speed governor has the tendency to increase same.

Similar to the standpipes act the safety valves; they must however, be sufficiently large to discharge at each oscillation a sufficient amount of water to cause a decrease of the energy of oscillation, notwithstanding the disturbing influence of the governor.

Also pressure-regulating devices have been provided which, in case of an increased pressure of the water, open a by-pass to the tail water; as, for instance, spring balanced accumulators, where the plunger, in case of rise of pressure, moves upward and opens a by-pass. Such devices are better than air chambers because they take energy out of the water, and also better than standpipes, because they do not contain a great mass.

An example of such a pressure-regulating apparatus, consisting of a spring balanced accumulator of large size and connecting with a by-pass valve, is shown on page 147, 1901, of *Schweizerische Bauzeitung.*

Any engineer who has to determine upon the dimensions of the pipe line is interested to know what increase in pressure will take place in the line if it is quickly closed, with a lower limit not to be exceeded, say two seconds, and if the water was flowing previously with maximum velocity corresponding to the turbines being totally open.

Increase of Pressure in a Pipe Line at Sudden Closing.

It shall first be investigated to what extent the pressure can rise in a pipe line if the latter is closed suddenly, so that the entire kinetic energy of the water flowing in the line has to be taken up by the elasticity of the pipe walls; viz., is used for doing work of deformation. If the pipes are

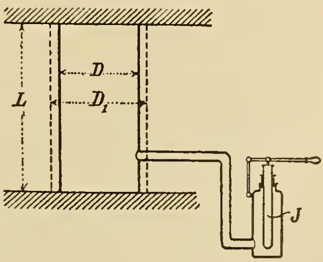


Fig. 6.

made sufficiently strong to withstand this increased pressure, one can do without any safety devices.

Suppose a cylinder of the diameter of D is clamped between two rigid plates of the unchangeable distance L, as shown in Fig. 6, and contains water under the specific pressure p. Now the contents J of a pump cylinder shall be pressed into the first cylinder, which results in increasing the pressure in the latter to p_1 and in enlarging the diameter into D_1. Apparently the annular volume must be

$$L\left(\frac{D_1^2\pi}{4} - \frac{D^2\pi}{4}\right) = J \qquad \text{II}$$

because incompressible fluid is assumed. The increase of pressure p_1 will largely depend upon whether the cylinder wall consists of elastic or unelastic material. Therefore the modulus of elasticity of the material of the wall is of prime importance. The specific strain K of the pipe walls is figured to $K = \frac{Dp}{2S}$, wherein S represents the thickness of the pipewalls, p the specific pressure, and D the pipe diameter. If by increasing the pressure the diameter D is enlarged into D_1, the circumference will be increased to the amount of a known quantity $D_1\pi - D\pi = (D_1 - D)\pi = \lambda$, and K will be increased to K_1, therefore giving $K_1 = \frac{D_1 p_1}{2S}$. According to the law of elongation of a bar, the change of length of a bar is $\lambda = \frac{Pl}{fE}$, where P represents the increase in load, l the original length of the bar, f the sectional area of the bar, and E the modulus of elasticity. If one assumes now a cylinder strip of 1 in. height cut open and developed, which is under tension on account of the increased load $\frac{D_1p_1 - Dp}{2}$, wherein D is the original length of a bar, one finds

$$\lambda = D_1\pi - D\pi = \frac{(D_1p_1 - Dp)D\pi}{2\,SE} \qquad \text{III}$$

as first relation between D_1 and p_1, and by substituting $D_1p_1 - Dp = D_1(p_1 - p)$, which is permissible on account of the slight difference between D and D_1,

$$2(D_1 - D)ES = D_1D(p_1 - p). \qquad \text{IV}$$

Herewith is to be combined the previously developed equation II, according to which the known contents of the pump cylinder

J must be equal to the larger cylinder volume less the original volume.

By pressing down the pump plunger, a certain amount of work, A, is performed, which, if for simplicity's sake a linear rise of pressure in the cylinder is assumed, is expressed by $f \times \frac{p_1 + p}{2} \times h = A$; and since $J = f \times h =$ the area of the pump plunger multiplied by the stroke, it follows $J \times \frac{p_1 + p_2}{2} = A$. This amount of work has been taken up by the walls of the cylinder as work of deformation. Suppose that the same deformation would take place if the amount of work A was conveyed to the water, not by a pump, but by suddenly changing kinetic energy contained in the water into potential energy, viz., pressure, — as it happens if a pipe line is suddenly closed, — the rise of pressure in a pipe line at sudden closure can be calculated.

If a horizontal pipe line in which water flows with a velocity v is closed suddenly, the amount of energy $A = \frac{FL \times \gamma}{g} \times \frac{v^2}{2}$ is used for dilatation of the pipe line if the length of the line is considered unchangeable. If the rise of pressure would occur evenly in the entire length of the pipe line, it could be calculated from the formulæ

$$A = \frac{J(p_1 + p)}{2} = \frac{L\pi(D_1^2 - D^2)}{4} \times \frac{p_1 + p}{2} = \frac{Lf\gamma}{g} \times \frac{v^2}{2} \qquad \text{V}$$

and

$$p_1 = \frac{D_1 - D}{2D_1 D} ES + p, \qquad \text{IVa}$$

one would need only to eliminate D_1 to obtain an equation for p_1.

The rise of pressure, however, does not take place uniformly, but will be greatest at the lower closing gate of the line, and will decrease towards the point of entrance. Therefore, the dilatation of the pipe line will be greater at the lower end, and at the entrance point of the water there will be none whatsoever.

The volume, which in the scheme drawing Fig. 6 corresponds to the amount of water pressed into the cylinder by the pump, will approximately take a shape as indicated in Fig. 7 by cross lines, viz., consist of a frustum of a cone less the contents of a cylinder, if linear increase of pressure is assumed.

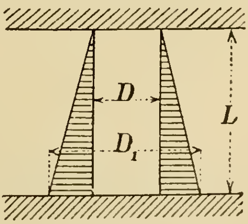


FIG. 7.

Therefore, we have now, instead of II, the equation:

$$J = \frac{1}{12}\pi L(D_1^2 + D_1 D + D^2) - \frac{\pi}{4} LD^2, \qquad \text{VI}$$

and

$$A = \frac{1}{12}\pi L(D_1^2 - D_1 D - 2D^2)\frac{p_1 + p}{2} = \frac{LF\gamma}{g} \times \frac{v^2}{2}, \qquad \text{VII}$$

which, with equation IV, permit of a calculation of p_1.

Horizontal pipe lines, however, do not occur with turbine plants. If the line is inclined, there will, at its end, exist a pressure which is equal to the head H less the velocity head $\frac{v^2}{2g}$. With flowing water, therefore, the distribution of pressure will be such as shown in the scheme drawing Fig. 7 by the cross-lined part.

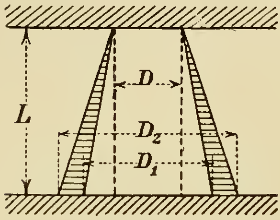


Fig. 8.

If, however, sudden closing takes place, the increase in pressure will be practically distributed, as shown in Fig. 8 by the cross-lined area, which is equal to the volume of the difference of two frusta of cones which on top have the diameter D (pipe with no pressure) and at the bottom the diameters D_1 and D_2. In this case, J, the increased volume, is the difference of the volume of the two frusta of cones, and one finds:

$$A = \frac{p_1 + p}{24}\pi L[(D_2^2 + D_2 D + D^2) - (D_1^2 + D_1 D + D^2)] = \frac{LF\gamma}{g} \times \frac{v^2}{2},$$

which is expressed more shortly,

$$L\pi\frac{p_1 + p}{12}(D_2^2 - D_1^2 + D_2 D - D_1 D) = \frac{FL\gamma}{g} \times v^2. \qquad \text{VIII}$$

D_1 has to be calculated from the prevailing head, deducting the friction head, and the formula takes the shape:

$$\pi(D_1 - D) = \lambda = \frac{Dp_1 D\pi}{2SE};$$

or, if the heads corresponding with the pressures p and p_1 are designated by h and h_1 $(p = \gamma h)$, where

$$h_1 = h\frac{v^2}{2g},$$

$$D_1 = D\left(1 + \frac{\gamma h_1 D}{2SE}\right). \qquad \text{IX}$$

From equation VIII, and from the equation resulting from the law of the extension of a bar,

$$2(D_2 - D_1)ES = D_1^2(p_2 - p_1), \qquad \text{X}$$

wherein was made $D=D_1$, one can, by eliminating D_1, calculate the pressure p_2. An exact determination will be difficult, because the expressions become very complicated. By the following procedure one finds a simple formula for the increase in pressure.

If one makes $D_2D=D_1^2$, since $D_2>D_1>D$, and all three quantities differ from each other a small amount only, equation VIII will read:

$$\frac{\pi L}{12}(D_2^2-D_1D)(p_1+p)=\frac{FL\gamma}{g}v^2.$$

If one further introduces for F the value $\frac{D_1^2\pi}{4}$; further for D_1D, once D_1^2 and once D^2; the correct result must be between the two results obtained by this last approximation; then follows:

$$\frac{1}{3}(D_2^2-D_1^2)(p_2+p_1)=\frac{D_1^2\gamma v^2}{g};$$

or,

$$(D_2+D_1)(D_2-D_1)(p_2+p_1)=3\frac{D_1^2 v}{g}.$$

By dividing this equation by equation X, the critical value (D_2-D_1) is eliminated and one obtains the quotient

$$\frac{(D_2+D_1)(p_2+p_1)}{2ES}=\frac{3D_1^2\gamma v^2}{g(p_2-p_1)D_1^2};$$

further:

$$(p_2^2-p_1^2)=6\frac{S}{D_2+D_1}\frac{E\gamma v^2}{g}.$$

Since the differences between D, D_1 and D_2 amount to small fractions of an inch only in most cases, one can make $D_1+D_2=2D$, and the relation is:

$$p_2^2=p_1^2+3\frac{S}{D}\frac{E\gamma v^2}{g}.$$

Making $h_1=\frac{p_1}{\gamma}$, and $h_0=\frac{p_2}{\gamma}$, in which h_1 and h_0 represent the heads corresponding with the pressures p_1 and p_2, it follows:

$$h_0^2=h_1^2+\frac{3S}{D}\frac{Ev^2}{\gamma g} \qquad \text{XI}$$

and the increase in pressure

$$(h_0)=h_0-h_1=\sqrt{h_1^2+\frac{3S}{D}\frac{Ev^2}{\gamma g}}-h_1.$$

Herein h_0 and h_1 are to be expressed in feet of water, S and D in units of length, g and v in feet, $\gamma=62.408$, and E in pounds per square foot.

Example.

In a pipe line of 54 in. diameter, water flows with a velocity $v = 6$ ft.; the lowest pipes of sheet steel are $\frac{3}{4}$ in. thick; the line is under a head of 200 ft. or a pressure of 86.8 lb. per sq. in. To what point will the pressure rise if the flow is stopped suddenly?

According to formula XI is

$$h_2^2 = 200^2 + 3\,\frac{0.75}{54} \times \frac{28\,000\,000 \times 144 \times 36}{62.4 \times 32.153}$$

$$= 40\,000 + \frac{2.25}{54} \times \frac{4\,032\,000\,000 \times 36}{108\,342.9} = 40\,000 + 3\,013\,432$$

$$= 3\,053\,432$$

$$h_2 = \sqrt{3\,053\,432} = 1\,747$$

$$(h_0) = 1\,747 - 200 = 1\,547 \text{ ft.}$$

The rise of pressure at the assumed, but in reality impossible, sudden closure will be over 1 500 ft., more than seven times p_1. The pipes would be strained

$$k = \frac{D}{2} \times \frac{p}{S} = 27 \times \frac{672}{0.75} = 24\,192 \text{ lb. per sq. in.,}$$

which would exceed the elastic limit, but still leaves some safety against rupture. The normal strain of the pipe is:

$$k = \frac{D}{2} \times \frac{p}{S} = 27 \times \frac{86.8}{0.75} = \frac{2\,343.6}{0.75} = 3\,124 \text{ lb. per sq. in.}$$

If the pipe was only $\frac{3}{8}$ in. thick it would be normally strained 6 248 lb. to the sq. in. At sudden closure the increase in pressure, however, would be less than with thick walls, because the thinner walls can give more.

For $S = \frac{3}{8}$ in.;

$$h_2 = \sqrt{40\,000 + \frac{1.125}{54} \times \frac{4\,032\,000\,000 \times 36}{2\,006.35}}$$

$$= \sqrt{40\,000 + 1\,506\,716}$$

$$= \sqrt{1\,546\,716} = 1\,243,$$

which is less than seven times h_1; there is further,

$$k = 27 \times \frac{540}{0.375} = 38\,880,$$

not twice the value of 24 192 found above, as was to be expected with walls of half the thickness.

The formula does not contain the length of the pipe line, which is quite evident; for each foot of length of the energy-carrying water there is a foot of length of energy-receiving pipe wall. This, of course, is correct only with the assumed sudden closure. It will be found in the following what tremendous influence the length of the line has upon the rise of pressure if

the closure takes place in a certain determined time, say 2 to 6 seconds; of course the values will be found smaller than with sudden closure.

Since in formula IV the velocity v for turbine pipes will always have a maximum between 6 and 9 ft., the modulus of elasticity E for plate steel has a constant value, γ and g also are fixed values, the increase in pressure at sudden closure depends only upon the ratio between the thickness of the pipe and its diameter and upon the pressure to which the pipes are subjected. The example which was figured out above shows that under high heads an absolute safety at sudden closure can be obtained only by extraordinarily increasing the thickness of the pipe, which would considerably increase the cost of the line. It is therefore natural that with long pipe lines one introduces safety devices which at sudden closure prevent its rupture. Of course one finds occasionally such safety devices where there is not the least danger for the pipe line. Such needless installations could happen only because on the subject treated herewith nothing has been furnished anywhere in the technical literature that is useful to the practicing engineer.

The energy taken up by the pipe walls is not destroyed, but the pipe walls will, after stationary conditions are reached again, contract to their original diameter and force back the surplus, but very small, quantity of water into the reservoir, which may be accompanied by some fluctuations back and forth. These conditions will be treated with the discussion of the standpipes.

Increase of Pressure with Definite Time of Closure.

The closure of a line can never take place instantaneously; a certain time for moving the closing mechanism will always be required, which might sometimes be very short.

It is to be investigated what rise of pressure will take place at the lower end of a turbine line, if the governor closes the turbine within a certain time, called Closing Time, designated T.

Apparently in this case a moving column of water, whose length is always equal to the length of the pipe line, is first retarded in its motion by increasing the resistances at the section of the discharge and finally stopped entirely. Herewith this column of water causes a shock against the closing apparatus, which is felt in the fluid as an increase in pressure, and, on account of the incompressibility of the water, is transmitted backwards towards the entrance section with decreasing intensity. For determining

approximately the greatest increase in pressure, it is sufficient to apply the law of impact, in which the energy contained in the water during the discharge is not deducted, however. It may also be mentioned again that the problem dealt with is a problem of undulation, as is evident from the previous discussions.

According to the law of impact $\int p dt = \int M dv$, the quantity of water in the pipe line, $M = \dfrac{LF\gamma}{g}$, is given by the length L, and the area F of the pipe line by the specific gravity γ of the water and by the acceleration of gravity g. The force of impact p depends upon the time within which the closure takes place; it is zero at the beginning of the closure, grows with the increasing closure and probably reaches its maximum at the moment of closure. The increase of the force of impact with the time t can take place according to the curves, *I*, *II*, *III*, in Fig. 9.

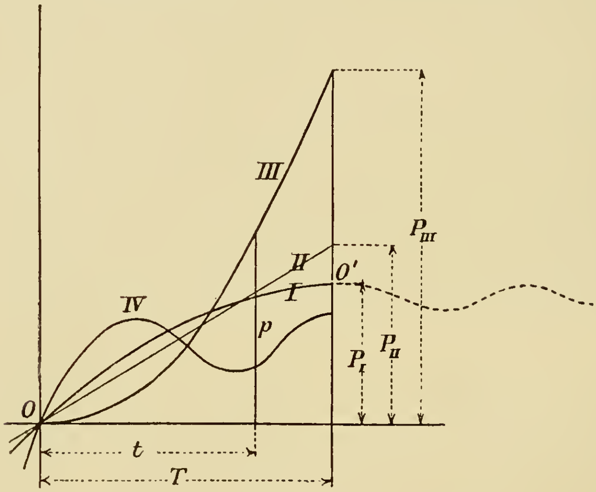


FIG. 9.

Suppose the increase in pressure takes place in direct proportion with the time, according to curve *II* in Fig. 9; then follows $\dfrac{p}{P} = \dfrac{t}{T}$, or $p = P\dfrac{t}{T}$, where P is the maximum force of impulse at the moment of complete closure. Entering this into the above integral equation gives:

$$\frac{P}{T}\int_{t=0}^{t=T} t dt = Mv; \text{ or, solved, } T = 2\frac{Mv}{p};$$

or,

$$P = 2\frac{Mv}{T} = 2\frac{LF\gamma v}{gT}.$$

Dividing this equation by the area F gives the force of impact per unit of area; and as it is customary to express the pressure in feet of water column (h), and $\gamma h =$ pressure per unit of area, the rise of pressure at the moment of close is $(h) = 2\frac{Lv}{gT}$, and the total pressure

$$h_2 = h_1 + \frac{2Lv}{gT}, \qquad \text{XII}$$

where h_1 represents the pressure before the closing began. In this equation the rise of pressure appears dependent directly upon the length of the pipe line.

If the rise of pressure took place with the time according to curve *III* in Fig. 9, for instance, in accordance with the relation $p = P\frac{t^2}{T^2}$, curve *III* being a parabola with its vertex in O and with vertical axis, the calculation would give:

$$\frac{P}{T^2}\int_{t=o}^{t=T} t^2 dt = M dv; \; P = \frac{3Mv}{T} = 3\frac{LF\gamma v}{gT};$$

$$(h) = 3\frac{Lv}{gT}; \; h_2 = h_1 + 3\frac{Lv}{gT}. \qquad \text{XIII}$$

The rise of pressure would be 50 per cent. greater.

Suppose p was dependent upon t, according to curve I as a parabola, with its vertex in O_1, the calculation gives:

$$P = \frac{3}{2}\,\frac{LF\gamma v}{gT}; \; (h) = \frac{3}{2}\,\frac{Lv}{gT};$$

$$h_2 = h_1 + \frac{3}{2}\,\frac{Lv}{gT}. \qquad \text{XIV}$$

Of the formulas XII, XIII and XIV, probably XIV is the most correct one, as it permits a continuation as a sinoidal line, according to the following vibrations of pressure, as indicated in Fig. 9. Through the influence of the elasticity of the pipe walls, however, the actual rise of pressure should be less than theoretically determined, about $h = \frac{Lv_1}{gT}$, which expression is occasionally used for calculating the rise of pressure. From the somewhat limited experience of the writer, however, formula XII gives values which agree with experiments.

Prof. A. Rateau (Paris), after analytic treatment in which, however, the influence of the dilatation of the pipe upon the rise of pressure is not considered, arrives at the expression

$$\frac{h_2}{h_1} = \frac{2 + n}{2 - n}, \text{ wherein } n = \frac{Lv}{gTh_1}.$$

Very completely, and with consideration of the elasticity of the pipe walls, and also of the compressibility of the water, the question of the hydraulic ram has been treated by M. L. Allievi. According to Allievi, if the time of closure exceeds a certain amount, which depends upon the length of the line and upon the velocity of transmission of the pressure vibrations in the column of water, the maximum rise of pressure takes place during the closure, drops then, and finally, towards the end of closing, rises again, as indicated in curve *IV* in Fig. 9. If the time of closure is long enough, several vibrations may occur within one period of closure. The maximum pressures are found somewhat smaller than according to Rateau, which must be expected since the latter neglects the dilatation of the pipe.

Example.

A pipe line 1 800 ft. long, of a diameter of 54 in., in which the water flows with a velocity of 6 ft., shall be closed in 4 seconds; the fall is 200 ft., so that the bottom pipes are under a pressure of 86.8 lb. We use formula XIV.

The maximum pressure at the end of closure is:

$$h_2 = 200 + \frac{3}{2}\,\frac{1\,800 \times 6}{2 \times 32.153 \times 4} = 200 + 62.979 = 263 \text{ ft.}$$

The increase in pressure amounts, therefore, to 63 ft., or $27\frac{3}{4}$ lb., and this result was found at an experiment, which was, however, unintentional.

The formula of Rateau gives in this case first

$$n = \frac{1\,800 \times 6}{4 \times 32.153 \times 200} = 0.42$$

and

$$h_2 = 200 \times \frac{2.42}{1.58} = 200 \times 1.532 = 306.4 \text{ ft.},$$

corresponding with an increase of head of 106.4 ft., or 46.18 lb., which fairly agrees.

The results found so far afford an insight into the construction of an empiric formula which gives the maximum rise of pressure at the end of a pipe line at closure within a certain time with a given initial pressure and under consideration of the elasticity of the pipe walls.

It is evident the rise of pressure must be less with increasing time of closure and have an asymptotic course with relation to the axis of time, since with an infinitely long time of closure there would be no rise of pressure. For $T = 0$, the final pressure must

have the value found in formula XI and the corresponding rise of pressure (h_0) is shown in Fig. 10 by the ordinate AO. The course of the curve is probably fairly correctly shown by the line AB, which can be substituted by one leg of a symmetric hyperbola, whose parameters are NN' and BN. Then $(h)(T+U)$ is a constant and also $(h_0)U$ a constant. If two relative values, for instance, (h_2) and T_2, are known, a further point of the curve is determined, for which $(h_2)(T_2+U)$ is constant.

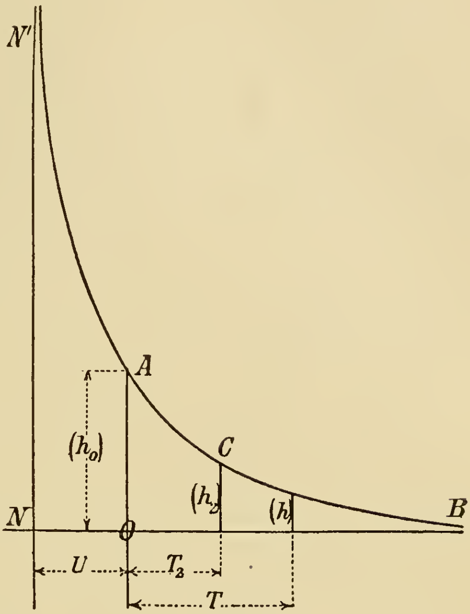


FIG. 10.

By eliminating the constant from the above three equations one finally finds for the maximum rise for a certain time of closure T,

$$(h)=\frac{(h_0)}{\frac{h_0-h_2}{(h_2)}\frac{T}{T_2}+1} \qquad \text{XV}$$

and finally,

$$(h)=\frac{\sqrt{h_1^2+3\frac{S}{D}\frac{Fv^2}{\gamma g}}-h_1}{\frac{T}{T_2(h_2)}\sqrt{\left(h_1^2+3\frac{S}{D}\frac{Fv^2}{\gamma g}\right)}+1-\frac{h_2}{(h_2)}\frac{T}{T_2}} \qquad \text{XVI}$$

where h represents the pressure prevailing at the beginning of the closure.

Introducing the values calculated in the previous examples by formulas XI and XIII, and for the latter the value of $h_0=1\ 747$, confirmed by experiment, $h_2=263$, $T_2=4$ seconds, gives for a fall of $h_1=200$ ft. and for a pipe line 1 800 ft. long, the formula

$$(h)=\frac{1\ 547}{\frac{1\ 747-263}{63\times 4}T+1}=\frac{1\ 547}{5.888T+1}=\frac{1}{0.0038\,T+0.00064}$$

which gives for a time of closure of 2 seconds, $(h)=121.3$, and for $T=10$ seconds, $(h)=25.9$.

The reducing influence of the yielding pipe walls is apparently more evident with shorter closing time.

Upon the question where the potential energy of the flowing water goes, one can reply that part of same reaches with the water with increased pressure the tailwater through the nozzle. The part transformed into pressure, viz., the resulting rise in pressure, does not remain passive. The pipes dilated by same gradually contract again and force the surplus of contents upwards, whereby on account of the kinetic energy of the water flowing opposite to the water entering the pipe, after some time a drop of pressure takes place at the lower end of the pipe; hereupon follows again a downflow and a somewhat smaller rise of pressure. And so the water in the pipe line oscillates for considerable time (frequently half an hour) up and down, until the pipe friction and the friction of the particles of water between themselves have destroyed the remaining amount of energy. Therefore, by sudden closure, an impulse for vibrations of the water in the pipe line is always given.

If the line is closed by the turbine governor not entirely but partially, a smaller rise of pressure takes place, which also can be calculated from formula XIII if for T that time is substituted that was necessary for partially closing the gate. In this case, however, the governor remains in action and helps considerably not to let the aforesaid vibrations come to rest, since it always closes when a pressure rise takes place, thereby still more raising the pressure, and always opens when the pressure falls in the line, whereupon the drop in pressure continues, etc. The vibrations of the water increase to a maximum and then remain constant. It may be mentioned that sometimes the entire pipe line takes part in these vibrations and even leaves its supports at points of change in direction; the writer had occasion to observe such occurrences.

The results calculated from formulas XII to XVI do not offer any guarantee, especially not if a longer closing time was figured upon, that the calculated rise of pressure might not be exceeded on account of the just-mentioned unfavorable influence of the governor. One has to deal with enforced fluctuations of the water in the pipe line, and the rising or falling pressure in the pipe line can, in very unfavorable cases, reach very high values on account of resonance of the vibrations.

An analytical treatment of these occurrences would be of theoretical interest only and hardly furnish results applicable in practice; in those cases, namely, where vibrations in the pipe line

are, in fact, caused by the governor, one is compelled to put the governor out of service unless one succeeds in stopping this condition by opening a by-pass or by other means, viz., changing the closing time, raising the degree of unsteadiness. The relation of these factors, to which secondary points are connected, that are beyond any calculation, is so complicated that it is impossible to expect the engineer, who has to start up the governor, to calculate and check up these vibrations.

The possibility of an occurrence of high pressures, however, under the conditions of service just mentioned, makes it seem advisable to dimension the pipe line in such cases sufficiently liberally to withstand even at sudden closure the rise of pressure occurring with a factor of safety of $2\frac{1}{2}$.

Standpipes, Free-Air Pipes.

The arrangement of standpipes can be such that the upper, sometimes flaring, edge is level with the water surface in the reservoir, so that, at a slight pressure rise, overflowing of the water over the upper edge of the pipe takes place. Or the standpipe can be higher, so that the overflow only takes place at a considerable increase in pressure. Both arrangements have been installed, the latter especially, where it was difficult to carry away the overflowing water.

One would think that standpipes, especially if installed at the lower end of the pipe line, would be capable of affording absolute safety against bursting of pipes. This, however, is not so, since at sudden closure part of the energy of the water flowing in the pipe line has to be used to accelerate the water in the standpipe. A resting body of water of such considerable volume requires for its setting in motion a fair amount of energy, and can in no case be suddenly brought from rest to a certain velocity. Therefrom results that also with standpipes considerable rise of pressure will occur at the lower end of pipe lines, and it only depends upon the ratio between the length of the pipe line and the height of the standpipe and upon the ratio between the thickness and the diameter of the pipe whether at all a standpipe affords an effective protection to the pipe line.

The pressure rises occurring with standpipes at the lower end of pipe lines at sudden closure of the line will now be investigated and calculated. A standpipe of the second type mentioned shall be assumed, whose height is such that an overflow over the upper edge of the pipe cannot take place even with the greatest occurring pressure rise.

First the simple case will be treated, where the velocity of flow in the pipe line is so great that the flow and discharge take place with a velocity due to the entire head, so that, if the water flows through the line with the velocity $v=\sqrt{2gh}$, the level of the water in the standpipe is very low, as shown in Fig. 11, and the amount of water contained therein can be neglected.

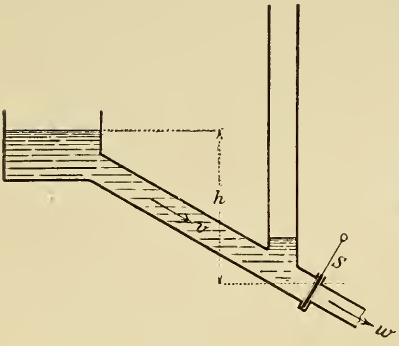


FIG. 11.

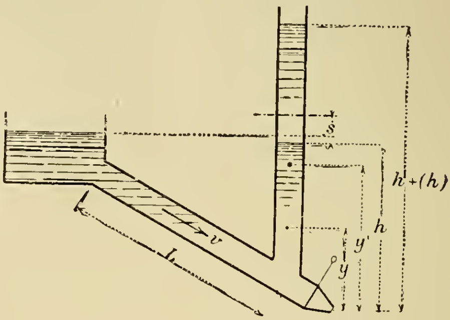


FIG. 12.

At sudden closure of the pipe line — for instance by the gate S — the water will first rise to the level h on account of the hydrostatic pressure; then, however, on account of the energy of the water stopped in its flow, beyond this, up to $h+(h)$. (Fig. 12.)

Suppose that for this additional rise (h), the entire kinetic energy acts, viz., the amount $A=\frac{FL\gamma}{g}=\frac{v^2}{2}$, the volume of lifted water $F(h)\gamma$ multiplied with the path of the center of gravity S, viz., $\frac{(h)}{2}$, will represent the work performed and it can be made $\frac{FL\gamma}{g}\frac{v^2}{2}=F(h)\gamma\frac{(h)}{2}$, which is expressed more simply, considering that $v=\sqrt{2gh}$,

$$Lh=\frac{(h)^2}{2};$$

or,

$$(H)=\sqrt{2Lh}. \qquad \text{XVII}$$

The maximum pressure occurring will, therefore, be

$$h+(h)=h+\sqrt{2Lh}=h+v\sqrt{\frac{L}{g}}.$$

The increase in pressure is, as has to be expected, the greater the longer the pipe line is and the more rapidly the water flows therein; therefore it also depends upon the head h, proportional to its root, however.

With turbine pipe lines the area of discharge from the nozzle is always considerably smaller than the area of the pipe line; therefore, the velocity of flow v in the pipe line is considerably smaller than $\sqrt{2gh}$.

If the area of discharge is designated by f and the velocity of discharge by w, on account of the law of continuity, $vF=fw$, therefrom with given areas and known velocity of the discharge of the water from the turbine gate, the velocity v of the water in the pipe line can always be easily found.

If the turbine gate is closed suddenly, an impact of the moving body of water of the mass $\frac{LF\gamma}{g}=M^1$ against the mass of water stationary in the standpipe $M''=\frac{hF\gamma}{g}$ takes place and the latter will be set in an upward motion up to a certain height (h), which will be reached after T seconds. In this case, also considering the dilatation of the pipe, which takes place during a short period after the impact and then disappears again, the energy of the flowing water is used exclusively to lift the entire column of water in the standpipe.

If y (Fig. 12) indicates the height of the center of gravity of the water column above the opening of discharge, and y' the position of the center of gravity after the water column reached its highest position, therefore $y'-y$ the rise of the center of gravity, then $y'\frac{h+(h)}{g}F\gamma-y\frac{h}{g}F\gamma$ is the work performed, which, on the other hand, must equal the kinetic energy of the water, so that one can say:

$$y'\frac{F\gamma}{g}[h+(h)]-y\frac{h}{g}F\gamma=\frac{LF\gamma}{g}=\frac{v^2}{2};$$

and since

$$y=\frac{h}{2} \text{ and } y'=\frac{h+(h)}{2},$$

it follows that

$$\tfrac{1}{2}[h+(h)]^2-\frac{h^2}{2}=L\frac{v^2}{2};$$

or,

$$2(h)h+(h)^2=Lv^2. \qquad \text{XVIII}$$

From this equation (h) can be calculated. The calculated value, however, will always be greater than the actually occurring rise in pressure (h), since part of the kinetic energy is used up in forming eddies and transformed into heat.

Solving the squared equation, XVIII gives

$$(h) = \sqrt{h^2 + Lv} - h.$$

Approximately also the time can be calculated after which this rise in pressure will be reached.

If the moving mass of water M^1 strikes the stationary mass of water M'', a deformation of the pipes must occur (since the water is assumed to be incompressible) which takes up the energy $\frac{M^1v^2}{2}$; while this dilatation takes place the motion of the mass M'' already commences, and when the dilatation after a very short period of time reaches its maximum value, the two masses of water move with the joint velocity v, which can be calculated as impact of unelastic bodies from the formula $v_1 = \frac{M^1 v}{M^1 + M''}$. This is the velocity the water in the pipe line and in the standpipe has after the impact. Now, however, the column of water in the standpipe rises; this causes a counterforce which retards the motion. At the same time the pipes gradually contract again and transfer the previously received energy again to the water. Finally, when the motion of the water reaches its end the previously calculated maximum value of the rise (h) will be reached.

For the motion to be considered here the differential equation, well known from dynamics, stands $\frac{d^2s}{dt^2} = -q$, where q represents the retardation of the water flowing in the pipe line. The counteracting force is the weight of the body of water rising above the original level in the standpipe. This counterforce is directly proportional to the rise; therefore can be expressed by $K = \text{Const.} \times s$. For $s = (h), K = F(h)\gamma$; therefore $\text{Const.} = F$ and $K = F\gamma s$.

The acceleration is given by the ratio of force to mass; therefore

$$q = \frac{F\gamma s}{M^1 + M''} = \frac{F\gamma s}{\frac{F\gamma L}{g} + \frac{F\gamma h}{g}} = \frac{sg}{L + H}.$$

Accordingly, the above differential equation becomes

$$\frac{d^2s}{dt^2} - \frac{sg}{L+h} = 0.$$

The latter equation is the one of the sinoidal curve. Making $\sqrt{\frac{g}{L+h}} = a$, the general integral is

$$s = A \cos a\, t - B \sin a\, t,$$

wherein $A = (h) \sin\beta$ and $B = (h) \cos\beta$, and β represents the phase of the vibration.

Since in the considered case the phase change disappears, since time is counted from the passing of the center position, $\beta = 0$, $A = 0$ and $B = (h)$, therefore

$$s = (h) \sin \sqrt{\frac{g}{L+h}} \times t;$$

for $s = (h)$, $t = T$; thus

$$(H) = \sqrt{\frac{g}{L+h}} \times T,$$

and

$$\sqrt{\frac{g}{L+h}} \times T = \text{arc} \sin 1 = \frac{\pi}{2};$$

or, finally,

$$T = \frac{\pi}{2}\sqrt{\frac{L+h}{g}}.$$

This shows that the maximum value of the calculable pressure rise at the end of the line will occur the later, the longer the line and the higher the standpipe. But it may be mentioned again, that, on account of the compressibility of the water and of the consequent velocity of travel of the pressure in the water, considerable deviations from the above results of calculation have to be expected, especially if the line is very long.

After having reached the highest position the water in the standpipe will drop again, and the entire mass of water will adopt a velocity opposite to the one previously had, which reaches its maximum at the moment the original level h is reached, but afterwards decreases again. Hereby the water is forced back into the reservoir, the level of water in the standpipe sinks to the amount s below the level h. Now again begins the flow of the water in the original direction, rise beyond the level h, and so forth.

Sinoidal vibrations of the water take place which, on account of several damping factors, amongst which the friction of the water against the pipe walls, gradually come to rest.

If the standpipe is of such shape that the water can overflow when it rises, the time T, after which the maximum pressure rise occurs, and the amount of the latter, change only inconsiderably, both becoming smaller. The only considerable influence the overflowing of the water has is upon the back vibration of the water, which is practically of no importance, since the mass of water has been reduced on account of the overflow. The back vibrations, therefore, become smaller, but the strain of the pipes

at the lower end of the line will be the same when the gate is closed as if no overflow of the water takes place.

Air Chambers.

From the preceding discussions of standpipes the action of air chambers may be immediately considered.

They act principally upon the pressure conditions of a pipe line like standpipes with which an overflow of the water does not take place and which are so short that the mass of the water contained therein, M'', need not be considered. The analytical investigation of the pressure conditions at sudden and rapid closure can be simplified by introducing the volume of the air chamber as a cylinder of the area of the pipe line and a height L_1, which can be brought into a simple relation to the length of the pipe line.

For the changes in pressure and volume of the air, the Mariotte Law can be applied with quite sufficient approximation.

After a rapid or sudden closure the energy of the flowing water will principally compress the air contained in the air chamber. If the maximum pressure in the air chamber is reached, which always will take place a considerable time after closing the gate, the air expands again and forces the water contained in the air chamber back into the pipe line; then follows again a pressure rise and so forth, since here the impulses of vibration are nearly the same as with standpipes. But as the mass of water is smaller than with a standpipe, the vibrations will take place at shorter intervals; the maximum value of the pressure rise will be the same as with standpipes.

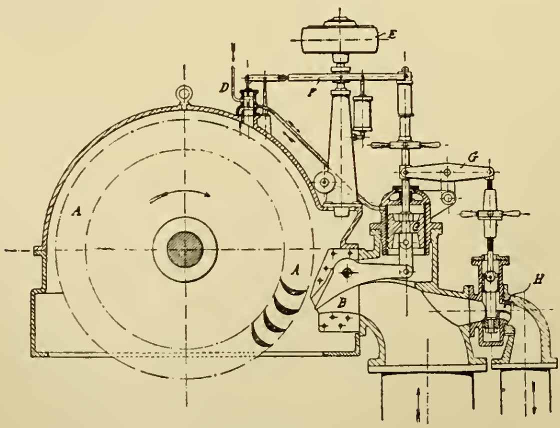


Fig. 13.

Air chambers are no more used to-day, so that a further investigation of the occurrences connected therewith can be dispensed with.

By-Passes (Synchronous Gates).

A clear illustration of a synchronous gate is given in Fig. 13, which shows an impulse wheel built by the firm of Messrs. Riva, Monneret & Co., of Milan, for the electric central station of the power transmission plant Villadossola-Intra.

The impulse wheel *A*, cast of steel, takes water from a single nozzle *B*, whose area of discharge can be reduced by means of a tongue with bell-crank. The bell-crank is connected by a link with a piston *C*, which is always pressed upward, if the space above the piston communicates with the atmosphere. If, however, pressure water enters this space, the water pressure acting upon the tongue opens the water inlet. The admission of the pressure water takes place through the balanced piston valve *D*, which is operated by a Hartung governor. In customary manner over-regulation is avoided by the floating lever *F*, moving back the valve *D*. From the piston rod a horizontal lever *G* branches off, which, by means of a link, operates the synchronous gate *H*, and this in such a way that with the tongue closed the entire maximum area of the nozzle is open in the synchronous gate. With the nozzle entirely open, however, the gate *H* is fully closed. Therefore, to the water in the pipe line the same discharge area is offered all the time, and a pressure rise or drop cannot take place in the pipe line with a change of nozzle opening. The discharge from the gate into the tailrace must be directed through a damping apparatus, which, as much as possible, destroys the energy of the discharge water; otherwise the issuing jet of water could easily destroy the masonry of the tailrace.

Synchronous gates of such arrangement, however, have the disadvantage that a maximum quantity of water is always used, not considering whether the turbine runs under full load or almost at no load. A storage of the water in the intake is impossible with this arrangement. Therefore, where storage basins are provided, and at times water has to be saved as much as possible, such synchronous gates cannot be applied, or have to be shut down when water is short.

In those cases, where the available quantity of water is sometimes less than the turbine can consume at full opening, the valve of the synchronous gate must be made adjustable, so that

with the nozzle of the turbine fully closed it only opens in accordance with the available quantity of water. This arrangement offers no constructive difficulties, but no fargoing economy of water can be obtained with it. In Fig. 13, the handwheel *K* is for this adjustment.

There are, however, also devices where the synchronous gate opens quickly at rapid closure of the nozzle, thus avoiding any pressure rise in the line, but then closes slowly, so that the dis-

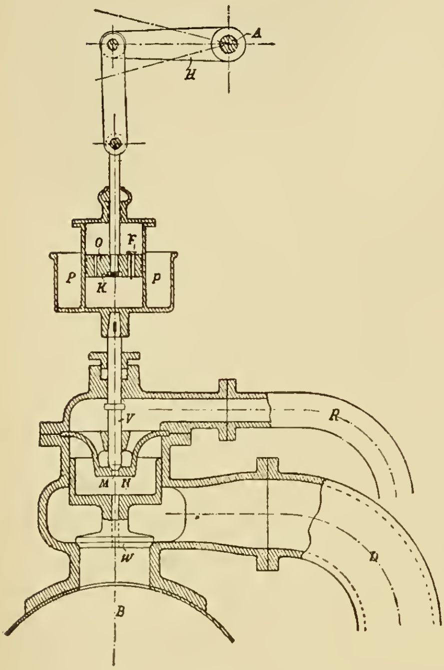


FIG. 14.

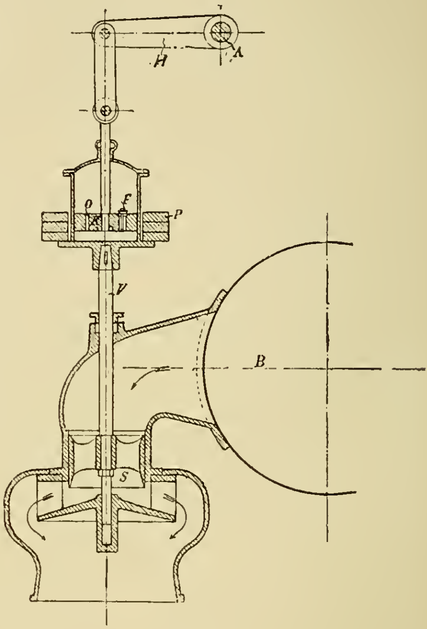


FIG. 15.

charge of water through the by-pass takes place only during a short adjustable period. Of the many possible designs solving this problem, the two illustrated in Figs. 14 and 15 may be mentioned.

In Fig. 14, the lever *H* is connected with the governor shaft *A* in such a way that with the closing motion of the shaft the left end of the lever rises. Hereby an oil cataract is lifted, since the oil above the piston *K* of the cataract cannot quickly enough flow down through a small opening *O* in the piston. In the bottom of the cataract a valve pin *V* is inserted, which closes an opening *M* in the upper cover of the discharge casing, through

which water flows from the chamber N through the pipe R into the tailrace. If this opening is uncovered by lifting the cataract, the pressure drops in the chamber N above the valve piston, and the latter, lifted by the pressure of the water upon the valve W, moves upward, hereby lifting the valve W, so that through the same, water can flow from the pipe line B through the curved pipe D into the tailrace.

When the lever H stops, the cataract slowly sinks. The velocity of this downward motion can be regulated at will by changing the opening in the cataract piston or by dropping weights into the cup-shaped extension P of the cataract, and finally the valve pin V again closes the opening M. Through a bore in the valve plunger, water enters the chamber N, whereupon soon the pressure in the pipe line is established in N and the valve W is forced downward and finally closed, since the diameter of the plunger is larger than that of the valve. At the downward motion of the lever H, the small valve F in the cataract piston comes into action, which permits the cataract fluid to flow quickly from below the piston above the same.

Less clever but simpler and, therefore, less subjected to various disturbing incidents, is the device shown in Fig. 15. As in Fig. 14, from the pipe line B a fitting branches off which terminates in a piston valve chest. The governor shaft A acts by means of the lever H upon the piston K of an oil cataract, which is rigidly fastened to the other end of the piston rod V of the piston valve S. The piston K has one or several holes O, and a valve F, which permit an easy drop of the piston when the piston valve is completely closed. The action of this device is analogous to the one described in Fig. 14, and, therefore, requires no further explanation. Weights P insure the drop of the piston into the closed position, which takes place the quicker the more weights are added. The piston of the oil cataract must be at least of such area as corresponds with the resistance against its upward motion plus the loaded cataract casing under the most unfavorable circumstances.

One would think that by installing such quick-opening and slow-closing devices the desired result was reached, viz., the pipe line protected against excessive strains, best possible economy of water guaranteed and the action of the governor improved by maintaining as much as possible constant pressure in the pipe line. In all three directions mentioned, however, cataract devices are imperfect in their performance.

So far only the pressure rise at rapid closing of a pipe line

has been taken into consideration. But with rapid opening of the supply pipe a considerable drop of pressure occurs in the pipe line, which unfavorably influences the action of the governor. The entire mass of water in the pipe line has, with an increased load on the turbine, to be accelerated from a velocity v_1, to a higher velocity v_2, and this cannot occur suddenly, but a certain time is required. However perfect the turbine governor might be, by opening the supply apparatus instantly at a drop of speed, in the first moment no greater quantity of water will pass through the turbine and only gradually the water will be accelerated to the required velocity. In the meantime, however, the governor has opened the supply apparatus much further than necessary and must close again, viz., it has worked too far. At the following closure the by-pass will be opened and a quantity of the valuable water flows needlessly into the tailrace, for there is no danger for the pipe line. Standpipes near the power house can be of favorable influence, since they supply ample water to the turbine in case of a sudden drop in pressure.

In plants where the load of the turbine is changing frequently and considerably, the loss of water at both closing and opening can become so great that it may nearly reach the one caused by a simple synchronous gate. Also with the closing of the turbine the cataract apparatus can become wasteful if it is not properly adjusted or if the originally correct adjustment has changed on account of various influences, viz., thickening of the oil, corrosion of the sliding surfaces, foreign bodies between the sliding surfaces. Then one cannot expect any more that with a certain rise of the lever *H*, corresponding with a certain closure of the supply apparatus, the valve in Fig. 14 or the piston in Fig. 15 is lifted just so high as to give to the water an area to enter the tailrace equal to the reduction of area in the supply apparatus. Rise and drop of pressure in the pipe line, which makes the governor oscillate, are then unavoidable. If then the apparatus remains in the open position, which can happen with the devices as Figs. 14 and 15 on account of sticking, if they are not sufficiently loaded, a considerable amount of water flows needlessly into the tailrace. If then the turbine gets a full load it can happen that not enough water remains to run it, that it slows down more and more and has to be shut down for cleaning the by-pass apparatus.

In electric plants, where frequently a fine is imposed upon interruptions of service, such would be most disagreeable. It is, therefore, advisable to always insert a gate between the pipe

line and the cataract apparatus so that the latter may be cleaned without interruption of service. If, however, such a gate is provided it will mostly happen that the attendants keep it closed all the time, thus feeling safer against disturbances. Especially in winter time, when the formation of ice may obstruct the apparatus in a manner hard to control, it is sometimes unavoidable to shut it down entirely. If then the service is satisfactory without it one cannot blame the attendants if they put it in commission only if visitors come to the hydro-electric power plant.

Conclusions.

From the preceding investigations it follows that under ordinary circumstances, viz., if the maximum velocity of the water in the turbine pipe line does not exceed 6 feet, if the pipe line is not very long, if the pipes are made of sheet iron and if the ratio between the thickness of the material and the diameter does not go beyond a certain point, a danger of rupture does not exist at the quickest possible closures.

If, under a high head and the resulting unfavorable relation between thickness of material and diameter of pipe, danger of rupture exists — this can be determined by formula XI — it has first to be considered whether by reducing the velocity of flow, eventually subdividing the pipe lines, this danger could not be avoided. Then any safety device can be dispensed with, the more so as they not always give a definite guarantee against rupture of pipes and only make the operation of the power plant more complicated. In such cases, where below the power plant the water has to be delivered continuously, by-passes similar to the one shown in Fig. 13 cannot be avoided If, however, the pipe line is very long and with closure within 2 seconds, a danger of rupture still exists, groups of spring balanced safety valves, applied at the lower end of the pipe line, are the simplest and best safety-device.

If in case of rapid loading or unloading of the turbine the governor gets to oscillating badly, on account of considerable pressure rise or drop in the pipe line, the opening of a by-pass, which has to be provided anyhow as a drain, offers a simple means for damping the oscillations. By suitable rules of operation the increases and decreases occurring in the load of the turbine can be made gradual, which considerably lightens the task of the governor. From experiences of the writer the operation of quick-acting governors with high heads and long pipe lines is still

feasible without any device to keep the pressure in the pipe constant, if the ratio of the energy A of the water flowing in the line to the maximum output of the turbine does not exceed the value $B_r = \frac{A}{HP} = 30$, and the fly-wheel masses are so ample that the ratio of the energy of the fly-wheel masses, $\frac{JW^2}{2}$, to the maximum output does not drop below the value $B_m = \frac{JW^2}{2HP} = 300$. Herewith an entirely perfect governor is assumed, whose closing time is 3 seconds as a maximum, with a degree of unsteadiness of the governor of 6 per cent. total. As long as the ratio of the energy of the water in the pipe to the energy of the fly-wheel masses, the characteristic figure $B = \frac{B_r}{B_m} = \frac{1}{10}$ is not exceeded, one can expect the governor to operate without periodic oscillations even without by-pass. This ratio also shows that if B is more than $\frac{1}{10}$ one is not yet compelled to institute by-passes, but can obtain satisfactory working of the governor by increasing the fly-wheel masses.

If the turbine takes little water only the governor wants to be aided occasionally by opening a by-pass, since, as mentioned, the inclination to oscillations of the line (breathing of the pipe line) is the smaller the faster the water flows through same. It always has to be borne in mind that the problem of regulating high-pressure turbines is a problem of vibrations, and an insight into the occurring phenomena is extremely difficult to obtain. The practicing engineer, whose endeavor is always to disclose the occurring phenomena and to reveal their causes, will very likely prefer to avoid all such devices, which, like cataract apparatus, will add to the already complicated conditions some factors which are entirely beyond calculation.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by January 15, 1909, for publication in a subsequent number of the JOURNAL.]

ROADWAYS AND STREETS.

By Louis C. Kelsey, Member of the Utah Society of Engineers.

[Read at the annual banquet of the Society, May, 1908.]

The term " road " is usually taken to be a way over which vehicles can pass, and carries the idea of a certain amount of artificial construction, maintenance and care; in fact, the word " road " is, as a rule, applied to the artificial construction, in many places usurping the more technical term " pavement." We speak of macadam roads, Telford roads, plank roads, corduroy roads, when in fact it is the pavement of these roads which is meant. It is artificial construction which appeals to the imagination whenever a road is mentioned. It is the contour, the surface, the pavement, in which the average citizen is interested.

It is the locating, the construction and maintenance of this surface or pavement which interest us as engineers. At the beginning of his advancement along the stony footpath leading to civilization it devolved on man to effectively and economically solve the problems of local, interurban, interstate and international traffic. The same problem confronts the engineer to-day. Emperors and kings have studied this problem before us, nations have risen and fallen because of its better or worse solution. Comfort, convenience, health and life are dependent upon the ease, speed and safety with which traffic is handled.

The great railway trunk lines that carry millions of tons of merchandise, the long feeders that traverse our various states in all directions, the little narrow-gage jerk water road that is held up to scorn, vilified as to management, but still patronized by the ever-grumbling public, serve their purposes on land.

The *Mauretania*, the turtle back, the huge battleship, the insignificant-looking torpedo boat, the fishing smack and the barge each serves its purpose on water, but all are dependent for usefulness and even existence on the cart, carriage, wagon, automobile and pack mule. The farmer must market his grain, the merchant deliver his goods, the miner must market his gold and the fisherman, his cod and herrings; without local roads of some kind these are all impossibilities. As the monarch of the forest depends upon the twig, as the great streams depend on the little rivulet, as the great nation depends for its life on the suckling infant, so do the great lines of traffic depend on the truck, the cart and the burro.

Cheops, who, like a half-fledged freshman, scratched his name on all he built and everything that was builded before him, is given the credit of building or paving a road that took 100 000 men ten years. The king of Babylon built or paved three great highways to foster commercial enterprise; Athens, Thebes and Carthage built and maintained roads for hundreds of years, and Rome, mistress of the world, paved that world for the passage of her armies and the transportation of her merchandise, while Gaul had paved trails, a few feet wide, for thousands of miles.

In the new world, the Incas, though supplied with no beasts of burden, yet builded paved footways approximately 2 000 miles long, supplied with shade trees and water. The first pavements made in the new world, after the advent of the white man, were not at the instance of the "city fathers," the "bloated office holders," or even the inhabitants of cities or towns, but were made by loggers, farmers and shipbuilders, of brush, logs and slabs, across swamps and marshes.

The older pavements were all of stone; in some cases these stones were of immense size. Rome used a foundation of lime, mortar and smaller stones, and her finished pavement was 3 ft. thick. This pavement would support enormous loads, but was rough and uneven, even after comparatively short usage. These pavements, on account of the size of the surface stones, were difficult to repair; indeed, the idea, when the first pavements were constructed, appears to have been "solid construction, and use to destruction." Great ruts were worn in the surface of the roads, but the pavement was considered to be in good condition because waterproof and solid. Indeed, when compared with the unpaved streets of London and Paris (the former even as late as the fifteenth century and the latter in the thirteenth century), these pavements might well have been considered the greatest of luxuries.

MacAdam and Telford, of England, were the first to construct cheap, practicable pavements; these pavements, popularly called macadam roads, were hailed with much praise and have been extensively used in Europe, England and America both for country roads and city streets. The materials for construction are obtainable in almost any district and can be prepared by either hand or machinery. The construction is simple and the class of labor required can be obtained anywhere.

It is, however, a popular idea that the construction of macadam pavement does not require technical supervision, either in the selection or deposition of materials; this idea is to a

great extent held by the engineering profession and is one great cause for failure in this class of pavement.

The chief cause for failure, however, is found in the lack of proper appreciation of the need of constant and painstaking repairs. Macadam pavement will deteriorate rapidly and almost irreparably in one season if neglected, causing total loss of the original outlay and frustrating the purpose for which the pavement was constructed. Constant supervision and repair are the price to be paid for even fair macadam roads.

Under the action of horses' hoofs macadam pavements wear solid, and where sheep in large numbers traverse these roads, the surface becomes hard and smooth; the action of the hoofs of the oxen and swine will, however, cause them to wear badly in ruts and holes, the soft cushionlike pads on the soles of their feet producing both a grasping and sucking action which draws the fine particles from between the small surface stones, allowing them to be easily displaced. The same effect, only to a much greater degree, is produced by the action of the pneumatic tires of automobiles and traction vehicles. Engineers watch with interest the effect of these vehicles on the long stretches of macadam roads in England and Europe. From the reports of park commissioners in the eastern part of our own country it would appear that macadam pavements are doomed; only an excessive amount of supervision serves to prevent the formation of ruts or holes which allow the introduction of water and loosening of the surface materials.

The cost of maintenance even under favorable circumstances being very large, by this new destructive factor will probably be increased to prohibition.

Our local experience with macadam has been to the present time limited, no true macadam pavement having been constructed until within the last few years. The sporadic efforts of street commissioners and road supervisors have, as a rule, been discouraging, and the lack of maintenance and supervision already threatens to destroy the macadam pavement constructed by contract.

The asphalt pavements of Salt Lake City are of several varieties, "asphaltic sandstone," "asphaltic limestone," "refined asphalt" and "residual pitch." The foundations for these pavements have invariably been constructed of concrete of good quality, and the pavements as a rule give good satisfaction and good service, though some experimental pavements have not proven satisfactory.

You gentlemen of the engineering profession will, of course, appreciate the value of a solid foundation in engineering work of any character. Concrete is recognized as a material possessing the qualities requisite for a foundation for almost any class of construction. The materials are obtainable in almost any district, the matrix before setting will adapt itself to any and all inequalities of the sub-grade, and, after but a comparatively short time allowed for setting, concrete possesses a strength equal to the best, and far exceeding the ordinary, natural stone. Added to this is its practical indestructibility when protected even to a slight degree. Benefited by the action of water, either in large or small quantities, but slightly affected by the majority of acids, gaining strength with age for an indefinite period, capable of being reinforced with metal and protecting the reinforcing metal from deterioration, concrete is, for construction purposes, the one realization of the ideal.

The wearing surface of asphalt is, as most of you are aware, the thing that is subject to the greater amount of criticism from the layman. This asphalt wearing surface may be roughly divided into two classes, natural and artificial.

The natural product, as used for pavements, is of two classes, "asphaltic limestone" and "asphaltic sandstone," or a combination of the two; these natural products are often refractory and difficult of manipulation, in some cases, possessing the quality of resistance to heat to the point of actual combustion, involving the result that any heat to which they are subject produces no apparent softening in the material until so great as to deteriorate the cementing quality. But few of these natural products can be successfully gaged in hardness or altered in quality without absolute refining. This limits, therefore, their use to such parts as have naturally the requisite qualities for wearing surface. If defective in asphalt, they are too hard; if "long on asphalt" and "short of other materials," they are too soft.

Asphaltic limestone possesses an objectionable quality of being slippery when wet, while the sandstone usually contains earthy matter, tending to cause granulation and consequent deterioration; both of the materials often contain small kidneys of material which deteriorate with exposure, leaving pits or pockets in the surface. Both of these materials, also, often contain large percentages of water and volatile oils which evaporate on exposure, leaving a hard slippery surface in the case of the limestone and a granular friable material in the case of the sandstone products. The impossibility of determining the future

characteristics of any of these natural products is a great objection to their use. A further objection to the natural product is found in its non-adhesiveness to the foundation, and only by the use of the distilled product can this objection be overcome.

Formerly the pavement wearing surfaces in this and other cities were laid directly on the concrete, but the amount of asphaltic cement in the wearing surface was not sufficient to produce adhesion to the foundation; therefore the asphalt was inclined to crawl or creep. This action may, however, to a large extent be obviated by the use of a binder composed of refined asphalt and broken stone, the use of the natural asphalt being confined to the wearing surface.

Paving with refined asphaltum appears almost an exact science when compared with the use of the natural materials, with the additional advantage of less cost. The binder course prepared with sharp, hard, broken stone mixed with asphaltic cement effectually prevents the creeping or crawling of the wearing surface. The wearing surface, composed of stone dust, sand, Portland cement and asphaltic cement, can be so gaged and mixed that the resulting matrix is of the exact quality, as regards density and flexibility, fitting climatic and traffic conditions. The admixture of sharp, hard sand with the asphaltic cement produces a surface fitted for traction vehicles, smooth but not oily, while horses find a footing much superior to wood, vitrified brick or cobblestones. As the vehicle resistance is entirely due to traction and not to either adhesion or rough surface, the propulsion of vehicles is easily accomplished. The surface is easily cleaned by the use of either water or brooms, the material is absolutely dustless in itself, sanitary, even to a certain extent antiseptic in its action, and even heavy traffic is beneficial to asphalt when proper width is allowed on wagon tires. Asphalt pavement on roadways of ordinary gradient approaches more nearly the ideal than any other pavement exploited.

There is, however, room for many improvements in the construction of the roadways. On streets of any length the question of expansion of the foundation is a serious one. Asphaltum expansion joints have been suggested and some experiments have been made with this material; they have, however, been to a great extent failures.

The proper construction of the joints along gutters and manhole covers is another serious problem which is worthy of the attention of engineers.

A far more serious question has arisen not only in our own

city, but in almost every city in the United States where pavements have been constructed; this is the question of the proper pavement for roadways having a steep gradient. Asphalt pavement can, it is true, be so constructed that it will furnish good footing for horses or traction for automatic vehicles on almost any practicable grade, as long as the surface is kept free from ice or snow. In our northern cities during the winter months this becomes an impossibility. If the snow was of such depth as to entirely form the traffic roadway, horses would be able to obtain footing if properly shod, but where the pavement is covered or partially covered with thin ice, or heavy frost, it becomes necessary to furnish a rough surface to insure good results. Brick, stone, concrete and wood have been successively tried, and each is open to serious objections. Whether it is possible to produce a satisfactory footing surface for winter traffic on steep grades is questionable. Some cities have resorted to the spreading of sand upon the paved surfaces, but this is also objectionable, and is only a very temporary relief, a slight snow or rain serving to render the work ineffectual.

Before ending this paper I wish to touch on the cheapest roadway that has so far been constructed, "an earthen turnpike," so called.

There is no doubt that the crowning of a roadway, even of earth, will greatly improve the drainage and surface conditions, and street supervisors should be encouraged to properly do this work. An earthen roadway should have a much steeper crown than is ordinarily given, and should not only be continuously sprinkled, but rolled, to keep in good repair.

Oiled turnpikes have been tried with some success in different cities, but they possess one objectionable feature that is inherent in the materials of construction. The action of even small particles of oil on rubber is exceedingly destructive; even the smallest particle of oil will in a short time cause irreparable damage to rubber tires. If the roadways were to be used by vehicles having metallic tires, oiled turnpikes would be a convenient substitute for macadam. That the oil is effective in lessening the dust there can be no doubt but its destructive effects on both clothing and rubber tires is no less apparent.

These objections are, however, reduced to a minimum, where the material used is asphaltic oil from which the lighter and more volatile oils have been eliminated by distillation.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by January 15, 1909, for publication in a subsequent number of the JOURNAL.]

PRACTICAL METHODS OF EXAMINING AND FITTING UP A HYDRAULIC MINE.

By H. A. Brigham, Member of the Technical Society of the Pacific Coast.

[Read before the Society, August 28, 1908.]

It is the purpose of the author to present to the engineering profession a brief review of the methods of hydraulic mining that were so successfully applied for many years in California, where these methods originated because they solved a problem; that is, it became essential to find ways and means to extract economically from the gravels the gold that nature had stored there in ages past for the use of man, and the unique manner of mastering the situation has found, and always will find, the admiration and approbation of technical men of all countries. It is so practical and simple a process that its utilization in mining will always remain an alluring expedient, and where the requirements for its successful operation exist, it seems almost a calamity to the commonwealth that it should have ceased to be the great industry it once was; and it is not unreasonable to assert that with an intelligent study of the physical surroundings it should be possible now, under certain conditions, of course, to make practical use of hydraulic mining on a large scale again.

That its processes may become familiar to others who have not had the opportunity to study its methods and results, the author has thought it of sufficient interest to describe, as briefly as that may be done, the practices of the old hydraulic miner, drawing mainly from his long experiences of many years past, dating back to the time when hydraulic mining was in its infancy in this country, and when it grew from small dimensions to assume cyclopean and colossal proportions.

While it is not the intention of the author to enter into any of the arguments and discussions that have been made so often, before the time and since the time that hydraulic mining was enjoined in the most promising part of our famous state, it does seem to him as though our technical men, our engineers and scientists should not give up all hope of an ultimate solution of this problem of rehabilitation, a problem which is worthy and deserving of the keenest attention of our greatest intellects, and

the magnitude of which should stimulate them to their best and noblest efforts.

The problem is worthy of it.

To give a bare outline of the possibilities of a part of the once famous hydraulic mining region of the Sierras, it may be stated in this connection that the ancient gravel channel, extending from French Corral on the west (lower end) to Moores Flat on the east, in Nevada County, Cal., covering a distance of some twenty-three miles, was probably the most extensive auriferous gravel deposit workable by hydraulic method known in the world.

The Columbia Hill section of this channel, reaching from Columbia Hill on the east to Cherokee and Badger Hill on the west, has only been worked in small and limited portions. It is about four miles long, over a mile wide in places, covering an area of more than two thousand acres, with a maximum depth of over 500 ft. This channel at a conservative average depth contains upwards of 900 million cu. yds. that hold out every inducement for profitable hydraulic mining, if means are found to carry away the tailings without restriction. This deposit is entirely free from overlying lava or other worthless material, containing little clay or bowlders of a size detrimental to hydraulic methods, except perhaps at the bottom, in the lower stratum, where larger bowlders are to be found. Gold lies here in paying quantities, distributed from the top to the bottom of this great gravel deposit; at the rate of ten cents a cubic yard which is a very conservative estimate, the treasure lying there and ready to be taken away represents 90 million dollars. It seems as though this were worthy of some thought and consideration. This region has been hydraulicked in a small way at any and all levels. Three different benches have been worked at several distinct points, in a haphazard way, leaving still a depth of at least 300 ft. of virgin gravel below the bottom of present operations.

A few statements of the results of actual workings may convey an idea of the wealth of this great mining field and of its future possibilities.

At the upper end of this deposit, at the Blue Bank Mine, Moores Flat, gold to the value of 91 000 dollars was taken out of an area somewhat less than one half an acre; this was the last hydraulic mining done at that end of the channel. At the very end of this hydraulic period a gross result of 29 000 dollars was achieved in a run of twenty days, dating from the preceding clean-up, netting more than 22 500 dollars for the run. The last

year's operation of the North Bloomfield Mining Company, ending at the time when the injunction was decided against hydraulic mining by the United States Circuit Court, netted a sum exceeding 300 000 dollars.

The following well-known mines are included in this section of the ancient gravel channel: the North Bloomfield, the Eureka Lake and Yuba Canal Company Consolidated, the Milton Mining Company,— all hydraulic mines,— besides several other very extensive hydraulic properties. Owing to the difficulties of working these deep deposits, requiring long drain tunnels, this part of the ancient channel, including the towns of Cherokee, Columbia Hill, Lake City, Malakoff and North Bloomfield, has been hydraulicked to the bedrock at only three points, viz., Moores Flat at the upper end, North Bloomfield and Malakoff some six miles below Moores Flat, and Badger Hill at the lower end. These statements are made to show that the process to be described has great possibilities.

There are no difficulties in the way of getting the gold out of the ground if we can agree upon some method by which we may dispose of the refuse material that holds this coveted metal in its grasp.

EXAMINATION OF A HYDRAULIC MINING PROPERTY.

Hydraulic mining consists of excavating and washing gravel by water under pressure through sluiceways provided with riffles for catching and saving the gold.

To make profitable use of this method it is essential to have a large volume of gravel containing sufficient gold, an adequate grade to utilize the sluices properly, dumping facilities for the disposal of the tailings, ample water under effective pressure for breaking down and washing off the material, and a supply of timber for building sluices or for other purposes.

Preliminary Examination.

In making an examination of a hydraulic mining property a general view of its situation, conditions and capabilities should be taken from the more elevated localities in its vicinity. If the view from these higher elevations is not too much obstructed it should be possible, with an aneroid and with a hand and slope level, to ascertain the general conditions and the adaptability of the locality for the purpose. This means an approximate determination of height, length, width and amount of the deposit to

be handled, and its general trend; the elevation of the bedrock of the channel or bottom of gravel deposit to be worked; the outlets and dumps for tailings, their relations to the height of the channel and the distance therefrom; the conditions and facilities for disposing of the tailings; the elevation, length, grade, required size, etc., of the sluices; the amount of water available, and the facilities for bringing it to the mine for economical and effective use; practical reservoir sites, both for storage, if necessary, and for receiving and distributing the water; available timber for building sluices and for general use; facilities for transporting the necessary material and supplies needed; labor conditions, climate, etc.

Detailed Examination.

If the view from these elevated positions should be too much obstructed to obtain the general oversight needed to form an opinion, and if no impossible conditions have been previously encountered, then more elaborate surveys may be necessary for obtaining this required information.

But if no feature is found fatal to the project, and all features appear reasonably good, then a more extensive and detailed examination should be entered into, commencing first with the *Titles*, which, if found perfect, should be succeeded by a very careful and exhaustive test of the deposits as to their value, extent, location, character, etc., and as to the elevation, formation, position and nature of the bedrock of the channel, or the bottom of the deposit to be worked. The methods of procedure for these tests will have suggested themselves from the preliminary examination; that is, whether by shafts, bore-holes, tunnels, cuts, exposed faces or otherwise.

Many and numerous samples should be carefully selected from all sections, or, at least, from a sufficient area, in order to enable one to arrive at a general average value; the extent of the entire deposit and the elevation of the bottom of such deposit should also be taken into account. A diagram should be made showing the immediate individual locality from which each sample was obtained. All the samples should be marked and carefully weighed; they should be reduced by pan or rocker, and the resulting gold, accurately determined and tabulated, should be finally entered upon the plan at the proper position.

If water in sufficient quantities can be obtained for the purpose, and conditions are favorable, an excellent method is to work off a measured section of the deposit by piping, or ground sluicing

through, or by shoveling it into small sluiceboxes prepared for this test. This plan, however, while giving a larger and consequently a better general average value than the pan or rocker test, may not be so reliable, owing to the greater difficulty in preventing a falsification of the natural conditions of the deposits, and this may call for an additional check.

The thoroughness, care and caution observed in locating and testing the deposit, and in ascertaining the position of the channel, bedrock or bottom of the deposit, are of the utmost importance, as the success of the whole undertaking is centered in and dependent almost entirely upon the reliability of these tests, and all the future examinations will be governed by and related to them.

When the results of this investigation have been satisfactorily verified, sufficient information as to the bedrock conditions should have been obtained to enable one to establish the elevation of the upper end of the sluice.

If all these preliminaries prove satisfactory, the next step should be to investigate the available outlet or outlets, dumpage facilities, and character of the bedrock or other ground through which the sluice will pass, whether by cut or tunnel; all these details should be thoroughly examined.

The elevation, grade and pavement of the sluices are of paramount importance, for the steeper the grade and the smoother the pavement, the greater the volume of fine material, and the larger the quantity and the sizes of stones and bowlders that can be run off with a given amount of water. Most large hydraulic mines have not fall enough, and are compelled, by their conditions, to be worked on inadequate grades. The determination of the elevation and grade of the sluice will depend upon the elevation and general condition of the available dump for the tailings, and also upon the relative positions of dump and deposit as to height and distance between them, as well as upon the amount of material to be deposited in the dump.

If the tailings can be discharged, firstly, into a torrential stream of sufficient size and current to run them away immediately and effectually; or, secondly, into a ravine or channel of ample grade or fall to carry them off by their own water; or, thirdly, if they can be discharged over a precipitous place where they will never accumulate high enough to back up into the sluices, the disposition may be considered as ideal, and the elevation of the lower end of the sluice may be established at once.

But if the tailings must be discharged into a place where

they will accumulate detrimentally, it will be necessary to observe that the sluice be located high enough to prevent any deposits at elevations that will cause them to back up into the sluice, choke it and render it unfit for further operations on that grade.

To establish the proper elevation for the lower end of the sluice under such unfavorable conditions of dump, surveys are necessary to determine the storage space available below the grade of the sluice and to obtain an estimate of the amount of material to be washed off and the proportion that will remain in the dump. If the ordinary conditions make the slope or grade too small, it may be possible to place the dump end of the sluice at a lower level and to utilize a giant near the outlet to elevate or stack up the tailings on one or both sides of the line of the sluice, to be extended as the dump becomes filled; or, the upper end may be placed at a higher level with the installation of a hydraulic elevator to lift the water and gravel into the head of the main sluice. Either one of these arrangements — giant at the dump end or hydraulic elevator at upper end of the sluice — will provide a steeper grade.

A giant or monitor is a device attached to the end of the mine pipe line, by which the stream may be controlled in direction. It consists of a metal tube so fixed to the pipe by flexible joints as to be moved readily in both planes. The tapering nozzle end varies in diameter from 4 to 9 in. and has a deflector attached at its extremity for the purpose of directing the stream readily to the proper point of attack.

This instrument of attack is the main implement of the hydraulic miner, and its successful development has made the process of hydraulicking what it finally became. It places a powerful stream of water, a confined force of great magnitude, at the immediate disposal of the operator, who utilizes this force by directing it, according to his judgment, to the point of attack. The width and the proportions of the sluice are governed principally by the volume of water to be used, and, to a small extent, by the character of the material to be washed, sand and fine gravel requiring a wider sluice, while large bowlders should have a narrower one for a given quantity of water.

For washing fine material and sand the following widths for sluices under varying amounts of water will answer, viz.:

For a 3-ft. sluice, 200 to 600 miner's inches of water.
For a 4-ft. sluice, 400 to 1 200 miner's inches of water.
For a 5-ft. sluice, 1 000 to 2 500 miner's inches of water.

For a 6-ft. sluice, 2 000 to 4 000 miner's inches of water.
For a 8-ft. sluice, 3 000 to 5 000 miner's inches of water.
For a 10-ft. sluice, 4 000 to 7 000 miner's inches of water.

If the deposit contain many large bowlders, the above proportions of water may be increased 10 per cent., or perhaps more.

The "miner's inch" varies greatly in different localities and is here assumed as equivalent to $1\frac{1}{2}$ cu. ft. per minute.

Most hydraulic mines contain more or less fine gold which cannot be saved with the ordinary sluices, no matter how well the sluice is paved or how carefully it is manipulated. Under such circumstances, if conditions make it permissible, one or more undercurrents are very desirable. It is preferable to locate them near and below the lower end of the main sluice, for the reason that by placing them midway, fully five feet of the available grade will be sacrificed in order to lead the water and tailings from the undercurrent back into the main sluice again.

By undercurrent the hydraulic miner means an enlarged construction of the lower end of the sluice, which is more particularly described hereafter and shown in the appended illustrations in detail. (See Sheet No. 3.) It is provided for the purpose of receiving the finer material, containing the fine gold which would escape without this precautionary measure, together with a certain quantity of the water in which this material is conveyed. The water, which is spread over a greater surface, slackens its speed of current, and this allows the smaller particles of the gold to settle in the riffles more readily. An undercurrent, therefore, arrests the flow more effectually than a sluice and retains any gold that the sluice may have allowed to escape.

Water Supply.

The matter of water supply for working the property should be thoroughly investigated. The quantity available, the amount of regular and constant supply, the height at which it may be delivered at the mine, the length of the ditch necessary to convey it and its proper grade, the character of the ground over which the ditch line or lines will pass; the necessity for flumes, the supply of timber for building them as well as for other purposes; the necessity of using pipe lines for crossing ravines or depressions and their length, size, pressure, etc., are features that require detailed inquiry.

If the supply of water is limited during the dry season, a survey of the drainage area and available sites for storage reservoirs may be requisite. It is necessary to ascertain the condi-

tions of the drainage area and the character of the soil for retaining the water; also the annual rainfall and how this is distributed through the different seasons of the year, as it is essential to have as steady and constant a supply of water assured as practicable in order that the washing may be carried on with as little interruption as possible.

The grade of the ditch should be as steep as permissible, taking into consideration the height at which the water is required at the mine and the nature of the ground traversed by the ditch. The cutting or eroding action of too swift a current for the soil must be avoided. The ditch must not deteriorate by the scouring action of the water running in it, and to prevent this its grade should be accommodated to the nature of the material into which it is cut.

Receiving Reservoirs.

One or more receiving or distributing reservoirs are very essential, and their capacity will depend upon the character of the deposit to be worked and the facilities for handling it.

If there is a wide face to the mine, so that washing may be carried on at several different points independently, or if there is little pipe clay and few bowlders to handle, and the material easily broken down and washed; if there are no hard bedrock cuts to excavate, and if the main line ditch is short and there is ample storage above the ditch line, then a small receiving reservoir will answer. But if the face is narrow and contracted, and there is much pipe clay to be broken, or many bowlders or stumps that require blasting and removal; or if there is much hard bedrock to be blown away, and with no storage facilities above the ditch, then receiving reservoirs of large capacity should be provided to prevent waste during the interim of cleaning up, shifting the giants, removing bowlders, etc., or while doing other work around the mine.

One of the receiving reservoirs should be near the head of the mine pipe line, so that the water may be quickly regulated for the giants or turned off without waste in case of accidents or other causes.

Cleaning Up.

This is the hydraulic miner's harvest, and consists in removing the pavement, collecting and separating the gold from the sand and from the material lodged in the riffles or interstices of the sluice pavement, a process that will be referred to again hereafter.

Pipes for the Mine.

The pipes that lead the water to the giants at the mine should be of ample capacity for carrying the entire quantity to be used without undue friction; seldom, if ever, is it good practice to run a portion of the water for the sluice over the bank. The pressure should be such as to allow the giants to be operated at a safe distance from the face, to prevent them from being injured or buried by the falling bank, and yet exert sufficient force to undermine the bank rapidly enough to insure an ample supply of gravel for the sluices.

It frequently happens that the lower portions of the bank are so compact or cemented that sufficient stream pressure cannot be obtained to cut it speedily enough to supply the sluice; other methods will then have to be resorted to. In such an event, it may be possible to get an ample supply of material for the sluice by piping above the hard gravel into a softer stratum, and far enough ahead to insure the safety of the giant from caves; the giant may then be brought closer to the bank, where it may now exert sufficient force to remove the remaining hard portion. While it may not be possible to cut this stratum fast enough to supply the full capacity of the sluice, it may be so arranged that one giant could be at work on this hard part of the bank while another could furnish the remainder of the gravel supply from a softer or caved portion of it.

Sometimes blasting has to be resorted to for loosening this hard material, which may be done by working the top off first and then blasting the remaining portion by means of drill holes, shafts or drifts; or it may be preferable to blast the entire face by running powder drifts into the bank at the bottom, with cross drifts at right angles at their inner ends; in this case, the powder is placed in the cross drifts and the main drift tamped solidly with dirt before exploding.

The latter method of blasting the entire bank, while frequently resorted to in the earlier days of hydraulic mining, when small streams of water were used, is now seldom required, as the large streams of water under high pressure as now employed are generally able to overcome the difficulty.

Details of Installing the Plant.

In discussing the preliminary examination for the exploitation of mining property, enough has been said heretofore to point to the fact that the arrangement of the sluice becomes one of the most important elements in the fitting up of the mine, for no

problem requires better judgment and more careful thought than the establishment of the grade, determined by the beginning and end elevations of the sluice and the distance between these two points.

With great hydraulic forces obedient to our immediate command, it is comparatively simple to remove large masses of material, and very cheaply, too; the principal difficulty, however, arises in providing an efficient carrier to convey them to the locality of disposition,— a conveyor that will always perform its many important functions with the least interruption or loss of time

It will be instructive, therefore, to discuss the practical installation of a sluice with more detail, referring to the preceding statements for a knowledge of the general principles that must guide one in determining the practical and economical possibilities, and also in studying the topography for the selection of the line.

The Sluice.

Practically this is nothing more or less than a flume of special design, built for the purpose of conveying water, which is, again, the conveyor of gravel containing a valuable metal that must be segregated from the mass and saved by making use of its greater specific weight. (See Sheet No. 2.)

The available cross-section may have a width of from 2 to 12 ft. or even more, and a height of from 2 to 4 ft., according to the volume of water used; it is made up of the sill, the posts and the side braces, the lining of floor and sides, and the walking plank on each side. There are no cross caps. The sluice contains the floor device for catching the precious metal, which, although almost primitive in its mechanical simplicity, is practically very effective and has been in use in one form or another from the earliest time in the history of gold washing. It consists of a pavement (which may be of wood, or of stone, or even of iron; in fact, of any suitable material), so placed and arranged that the greatest amount of gravel may be effectually conveyed over its surface; at the same time it will have to afford the gold an opportunity to leave the mass in which it is moving along; it must intercept it and find lodgment for it in the numerous pockets, or receptacles, that have been provided between the blocks for that specific purpose.

Reference may be had to the illustration shown on Sheets Nos. 2 and 3 for details of construction.

In constructing the sluice, great care must be taken that the grade be uniform throughout its length, as a short section of lighter grade will govern the transporting power of the material for its entire length, while a section on a steeper gradient will cause a more rapid wear of the pavement, and this may necessitate a change or renewal of it on the steeper grade before it is really required on the rest.

A straight sluice is an ideal one, but this is not always practicable. In making turns or bends in a sluice, great care should be taken not to make angles so sharp that the flow of the water is thereby retarded or the surface of the water unduly disturbed which will cause a stoppage of the material, thereby choking up the sluice. Where an abrupt bend is unavoidable, it must be so constructed that the current will adapt itself to the turn and retain its velocity and smooth water surface. This can be accomplished by cutting the sluice boxes into such lengths that a short turn may be effected by a small curvature to each joint.

Where the proposed turn cannot be made with the full length (12 ft.) of the boxes, by giving each box a 5-in. turn, the boxes may be made in shorter lengths, say 6 ft., each of a 4-in. turn; if necessary to make a still shorter curve, the boxes may be made 4 ft. long each, with a 3½-in. turn; even shorter lengths may be used if necessity requires it. At both ends of a curve the turn should be eased.

The outer curve, or that of the longer radius, should be raised a little above the inner one, say ⅛ to possibly as much as ⅜ of an inch per foot of sluice width, at the same time increasing the grade a little to overcome the check. Around a very short turn the gradient should be increased as much as 15 per cent., or possibly a little more than that. With this precaution few instances are likely to occur where a turn cannot be successfully made without sacrificing more than a few inches of the available grade.

The height of the sluice — the sides — will depend upon the height and condition of the ground through which it passes. If the sluice is to be in a deep cut, in hard ground, high sides will be unnecessary, and 30 inches may be enough. This will not only save lumber but it will also prevent a heavy strain on the sluice bottom, and, in the case of cleaning up and changing the pavement, it will afford a handier opportunity for piling the loose blocks on the top, which is so much easier to reach.

If a sluice located in a deep cut of hard material as just described should fill to overflowing because the gravel is run into

it too quickly, or if it be obstructed in any way to cause an overflow, the water will at once return to the sluice without aid as soon as the flow of the gravel is reduced or the obstruction removed. On the other hand, if the ground of the outer cut is soft and liable to be eroded by the created current, or if it lie lower than the top of the sluice, care must be taken that the sides are high enough to prevent any overflow during an obstruction, for if this should occur in a case like this, even to a slight extent, while the sluice is fully charged with material, it would cause a congestion, and unless the flow of gravel from the mine be checked immediately, the entire head of water will overflow the sides, and it cannot be brought into the sluice again until the gravel is removed, which will cause a long and expensive delay.

Preparing the Bed for the Sluice.

Where the sluice is to be laid in a deep open cut, and the character of the ground is such that it may be washed away, and where the necessary quantity of water may be had under adequate pressure, it will prove economical both as to time and cost to utilize a giant in preparing the bed for the sluice. If water be available, but without pressure, recourse may be had to ground sluicing. The bed may be prepared in this way by getting it almost down to the proper grade and finishing it by hand labor subsequently.

Where there is a large amount of material to be removed in this manner in order to prepare the bed for the sluice, a section may be hydraulicked or washed off and the sluices built therein and paved; it may then be possible and practicable to work off another section of the ground through the sluice already completed.

In this way the sluices may be extended and continued until the field of operation is reached.

Tunnel.

In opening up a mine, a drain tunnel for the sluice is sometimes necessary, with a shaft at its head for the purpose of washing the material through it into the sluice in the tunnel.

The tunnel should be of sufficient width to afford room to place the loose pavement upon the top of the sluice while cleaning up and changing it. While it is possible to place the loose pavement on the bottom of the sluice at such time, it becomes a slow and awkward process, as it must be shifted several times before completing the clean-up. If the head of a sluice tunnel is located

in deep bedrock, or if a shaft is used for any length of time in running material through it, the portion that is subjected to the continuous wear and tear for long periods should be securely timbered and lined to prevent its ultimate destruction.

Should the bottom of the shaft be in soft ground, liable to be eroded by falling water and material, it must be securely timbered to prevent undermining at its lower end. If the bedrock be very soft, it may be necessary to extend the timbering of the shaft downwards a few feet below the bottom of the sluice. The bottom needs no protection other than to prevent the sides from caving.

In order to prevent a choking of the tunnel from an oversupply of gravel, it should be made somewhat higher from the shaft downwards for a distance of 50 feet or more, say, to the extent of 3 or 4 feet at the shaft and tapering thence to the normal height of the main tunnel in this distance. If the tunnel is to be continued past the shaft it will prove expedient to place the shaft to one side of the tunnel and far enough from it so that the shaft may be utilized for washing the material, or for running waste water through it without endangering the sluice after its extension ahead and beyond the shaft. This can be done by running a short branch from the main tunnel and placing the shaft at the head of this branch.

The main tunnel should be extended ahead at opportune times and another shaft constructed to be in readiness for continuing the washing without delay when the cuts from the former shaft lose their grade, become too deep in the bedrock or too long to justify their farther extension.

If, in placing the sluice in the tunnel, there should not be sufficient room on each side to put the loose pavement while cleaning up, the sluice should be placed close to one side, leaving all the space on the opposite side.

Drains.

If there be a large quantity of seepage water from the mine, t may be desired to construct a drainage box for conveying this water during the time that the pavement is replaced. This drain may be located on the outside of the sluice, its upper elevation even with the top of it. While this will require a high temporary dam to raise the water into the drain at the upper end of the section to be cleaned up, it has the advantage of clearing easily, while clearing would be difficult with a closed drain placed on a level with the bottom of the sluice, as is sometimes done. Unless

there is a large amount of seepage water to handle, the drain may be dispensed with, for the miners soon become accustomed to paving the sluice with considerable water running in it.

Before turning on the water for mining, a signal should be placed near the upper end of the tunnel, a short distance below the shaft, with a connection therefrom to some point where it can be readily seen from the mine, so that it may be indicated at once if the sluice begins to fill with an overload of material, or from some other cause, so that the water may be allowed to run free of material until the sluice clears itself, when washing may be resumed.

Construction of the Sluice.

This may be seen in detail on the illustration shown on Sheet No. 2.

For the bottom 1½-in. boards will answer and for the sides 1¼-in. The bottom is to be surfaced on the top, the sides to be left in the rough. The sills may be 4 by 5 in. for sluices up to 5 ft. wide, and 4 by 6 in. for wider sluices.

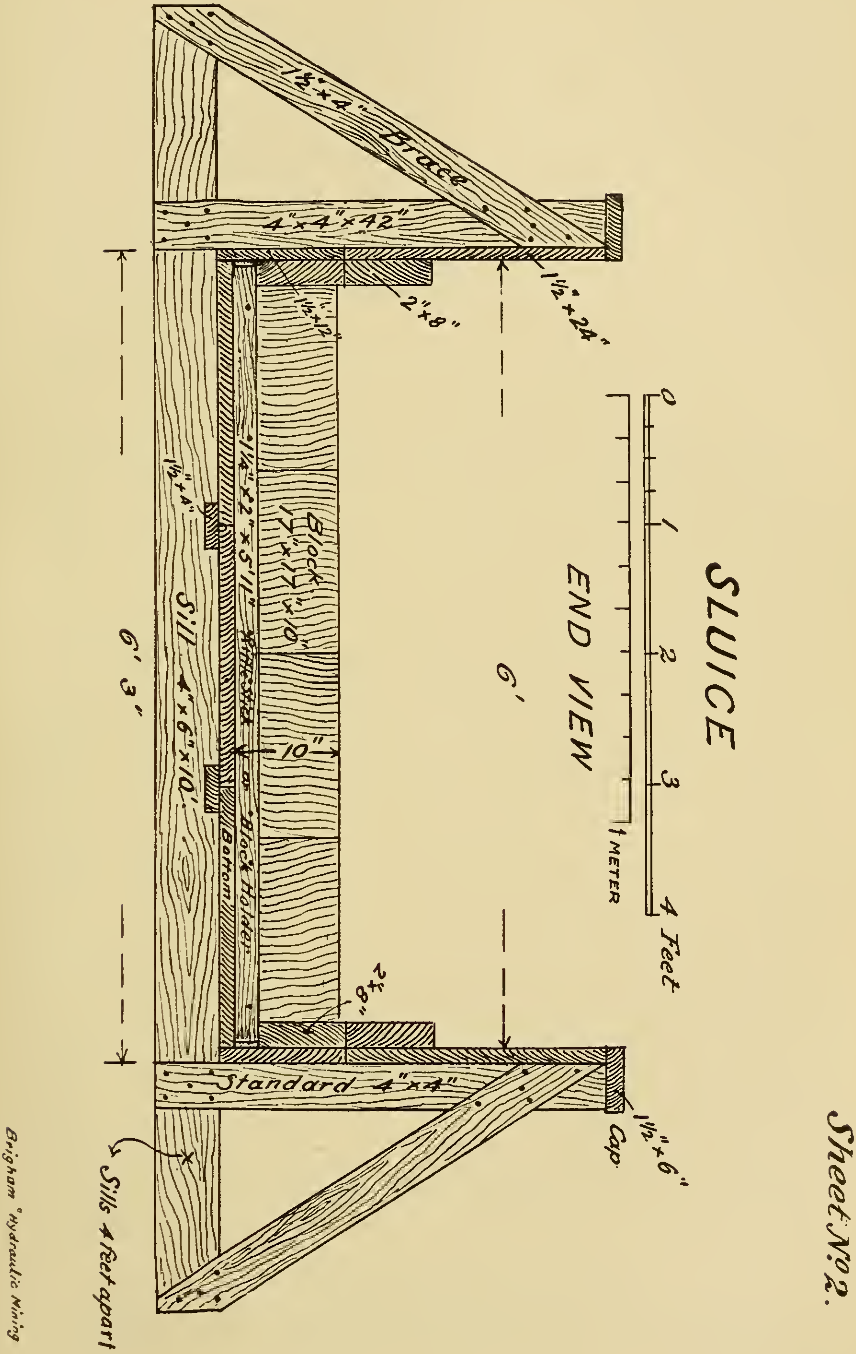
The posts or standards are suitable at 4 by 4 in., and the post braces should be of 1½- by 4-in. timber. The bottom ties must be firmly laid so that no settlement will occur if the sluice should become filled with gravel. All joints in the bottom should close perfectly to prevent leakage of quicksilver and consequent loss of fine gold.

If there be springs along the line of the sluice, their water should not be allowed to back up and run over the top, as the pressure may force up the bottom, especially while cleaning up. Cutting a vent hole near the end of the side board, ½ in. above the bottom board, with the bottom side of the hole sloped upwards towards the outside of the sluice, to prevent the quicksilver from running out, will overcome this difficulty. Several of these holes should be made along the sluice, especially where there is danger of water backing up on the outside.

A longitudinal cap or running board, say 1½ by 6 in., should be securely placed on the top of the sides, nailed flush with the inner edge of the side board to prevent this from bulging into the sluice. The sides should be well braced against inward or outward bending. The sluice must be anchored down and well protected from rising bodily, which may be caused by exterior water pressure.

Pavement.

If suitable timber may be obtained at reasonable prices, a block pavement is generally the most desirable, especially for


SLUICE
END VIEW
Sheet No. 2.
1½"×4" Brace
4"×4"×42"
1½"×24"
2"×8"
1½"×12"
1¼"×12"×5'1"
Block Holder
Block 17"×17"×10"
6'
6' 3"
Sill 4"×6"×10'
1½"×4"
10"
Bottom
Standard 4"×4"
1½"×6"
Cap
Sills 4 Feet apart
0 1 2 3 4 Feet
1 METER
Brigham "Hydraulic Mining"

the upper end of the sluice where the principal portion of the gold particles will settle, and where the pavement will have to be removed more frequently for this reason. If the sluice must be longer than necessary for the simple saving of the gold, it may be desirable to pave the lower portion with other material, if a suitable kind is obtainable and at reasonable cost.

Rocks or bowlders make a lasting pavement and, under favorable conditions, may be desirable if of very hard material and of such shape that they may be securely held in place, particularly if they do not present too uneven a surface for the gravel and bowlders to run over. Rocks blasted by dynamite are not suitable for pavement, owing to the shattering effects of the dynamite.

It will be almost impossible to pave a sluice with stones and to make a surface so smooth and even that the same amount of gravel and bowlders can be run over it that will run over a block pavement on the same grade; therefore the portion paved with rock should have a proportionate increase of grade. This is of great importance as the volume of gravel and bowlders that can be run through the sluice depends upon the amount that can pass its section of least transportability; that is, that particular portion which has the least grade or the most uneven surface.

If very hard rock be used in the pavement it will probably outwear any block pavement five or more times in the matter of requiring it to be changed by reason of an uneven wear.

The problem of working successfully by hydraulic process is this:

To get as much material into the water as the current will transport through the sluice, and to convey this volume continuously without interruption.

Steel bars and old railway iron make a very good pavement, for as much fine material and more bowlders can be run over them than over a block surface. This iron pavement is generally more expensive, especially if the mine is situated at a great distance from a railway and lacking cheap transportation facilities. But it has the advantage of wearing much longer than blocks, and it needs less changing in consequence, an operation that always constitutes one of the largest expenditures and delays in hydraulic mining, especially where there are block pavements in long sluices.

Details of Block Pavement.

Blocks for pavement are generally made by sawing them from the trees in lengths suitable for the purpose for which they

are to be used, say from 4 inches long, where a small head of water is to be used, to 12 inches, or even more, where a large volume of water is run. These blocks are squared to such a size that a given number will reach across and just fill the sluice from side lining to side lining. One or more different sizes may be used for the same sluice, but each size should be square, so that when replacing the pavement the blocks may be turned around in any manner best suited to make the smoothest surface possible. (See illustration, Sheet No. 2.)

It is very essential that the blocks be hewn squarely and truly and placed so tightly together that no crevice is left parallel with the current, for a small crack, more particularly if two or more are in line, will soon become larger by wear and will compel a cleaning-up and a change of the block system sooner than if this had been properly laid the first time; the wear, in that case, will be so irregular that it will be found most difficult to relay a satisfactory and smooth surface again without eliminating the uneven blocks.

Side Lining.

The side lining of the sluice shown in the section on Sheet 2 as two 2 by 8 in. planks on each side has two purposes: To protect the permanent side of the sluice from being worn, and to hold the blocks and prevent them from rising and floating away. (See Sheet No. 2.) The thickness of the side lining will depend upon the width of the sluice and the quantity of water used.

With a narrow sluice and a small head of water, 1-in. lining will answer, while with a wide sluice and large volume of water, 2- to 3-in. lining is required, and this should reach sufficiently above the blocks to prevent the wear of the permanent side planking.

Boards are generally used for this purpose, but where there is a large amount of wear, blocks are sometimes utilized, especially if the sluice is located in a tunnel or at other places where it is inconvenient to change the lining.

These blocks are made somewhat similar to block pavement by sawing them in $2\frac{1}{2}$ to 3-inch lengths from the tree, dressed to uniform sizes for top and bottom, and of any convenient length for the sluice. They are nailed to the side similar to board lining.

Riffle Strips or Block Holders.

These strips or sticks answer two purposes also: To hold the blocks in place and prevent their floatage, and to create the in-

tervening space, crosswise in the sluice, between two series of blocks, known as the riffle, whose office it is to hold the quicksilver and to catch and retain the gold particles.

The dimensions of the sticks vary under different conditions and under differing opinions of miners. They must be strong enough to prevent the blocks from lifting and broad enough to furnish an ample-sized receptacle between the blocks to harvest the gold. The thicker or broader they are, that is, the wider the space between the blocks, the greater and the more uneven will be the wear on the block edges, and, consequently, the rougher will be the surface of such a pavement after the blocks have been turned and changed around.

If large bowlders, especially angular ones, be run over a pavement, it will become manifest that the wider the riffle, the more will the lower edge of the blocks be broomed and split off, which will make a very rough surface upon turning.

If the " riffle pieces " are too high, the receptacle for the gold will become shallow and sometimes obliterated when the pavement is worn thin. A " riffle strip " $1\frac{1}{4}$ by 2 in. is sufficiently strong for a sluice 5 ft. wide; a wider sluice requires a stick of $1\frac{1}{4}$ by 3 in. dimensions. (See the illustration on Sheet No. 2.)

Laying a Block Pavement.

A good method is to nail the side lining against the permanent side of the sluice, leaving the lower edge $2\frac{1}{4}$ inches above the bottom, where a 2-inch riffle strip is to be used, which will allow the end of the riffle strip to be freely inserted under it for the purpose of preventing the strip from lifting with the blocks when the water is turned on.

After the side lining is properly secured to the permanent side of the sluice, a row of blocks, all of the same size, is placed across it and wedged tightly together and against one of the side linings; thereupon a riffle stick is slipped under the side lining and pushed against the side of the blocks, raised up tightly against the bottom of the lining and nailed to each block with headless or small-headed nails, leaving $\frac{5}{8}$ of an inch of the head projecting for insertion into the next row of blocks.

After one row is properly secured in the manner described, another row of blocks is placed across the sluices, the blocks are pried close together and set up tight against the side lining, in this case opposite to that wedged to in the case of the preceding row, and in this manner breaking joints in the block system. The blocks are thereupon driven solidly on to the nails and

against the riffle stick. Another riffle stick is inserted after this, and the process is repeated in the same manner as just described and continued in both directions, up and down the sluice, provided there is no running water in it to interfere with the laying up stream.

After the entire sluice is properly paved and everything in readiness for the water to be turned on, washing should be commenced with a small head of water until all the spaces are solidly filled with sand and fine gravel, after which the full head of water may be utilized.

In beginning to wash through a new sluice, where the ground on the outside is higher than the top of the pavement, caution must be used that the water does not collect on the outside to a greater height than on the inside, unless the sluice has already been properly anchored or weighted down. Unless it has been filled solidly with rock or dirt to the top exteriorly, it should at once be made to overflow until the outside is filled completely with dirt, even with the top, if possible, after which, if this be properly done, no further anxiety need be had as to the possibility of lifting the sluice.

If the channel or face of the gravel deposit to be worked is too wide to be washed through a single sluice or cut, one or more branches are made necessary from somewhere near the head of the main sluice.

The distance between these branch cuts or auxiliary sluices will depend upon the character of the gravel deposit; in the case of a deposit containing much hard clay to be broken up, or large quantities of bowlders to be conveyed, these branches should be nearer together than in a case where the deposit is composed entirely of fine gravel and sand.

If the deposit contains adhesive clay, especially near its bottom, so that it cannot be worked separately and apart from the pay-gravel, then the branches should be close to each other and held at such a steep grade that they will keep themselves entirely clear, allowing nothing to collect therein while washing this pay-gravel; or, what may be still better, the sluices should be built up as closely to the bank as possible, to secure the gold quickly from the clay, for the reason that the sticky clay has a decided tendency to take up all the gold that it may come in contact with, and it will carry all this, or nearly all that it has once picked up, entirely through the sluice and away from the undercurrents at a total loss to the mine. Where the deposit is very deep and extensive it may be advisable to hydraulic it

off in two or more successive benches, which will give a steeper grade for working the upper levels.

Speaking generally, a bank of 250 to 300 ft. is as high as can be conveniently hydraulicked in one bench, although, under favorable conditions, it may be practicable to work with safety from a single bench a bank that exceeds 300 ft. in height. These conditions are: A large pressure for the giants; compact gravel, that will not run to any great distance from the bank when falling from the top in slides or avalanches, jeopardizing the safety of the giants; and also a wide open and roomy pit will make it possible to operate on banks that may exceed the ordinary practicable limits of height.

Referring again to the process of *cleaning up*, which is resorted to whenever it is deemed necessary to collect the yield of the mine, some additional statements may be made.

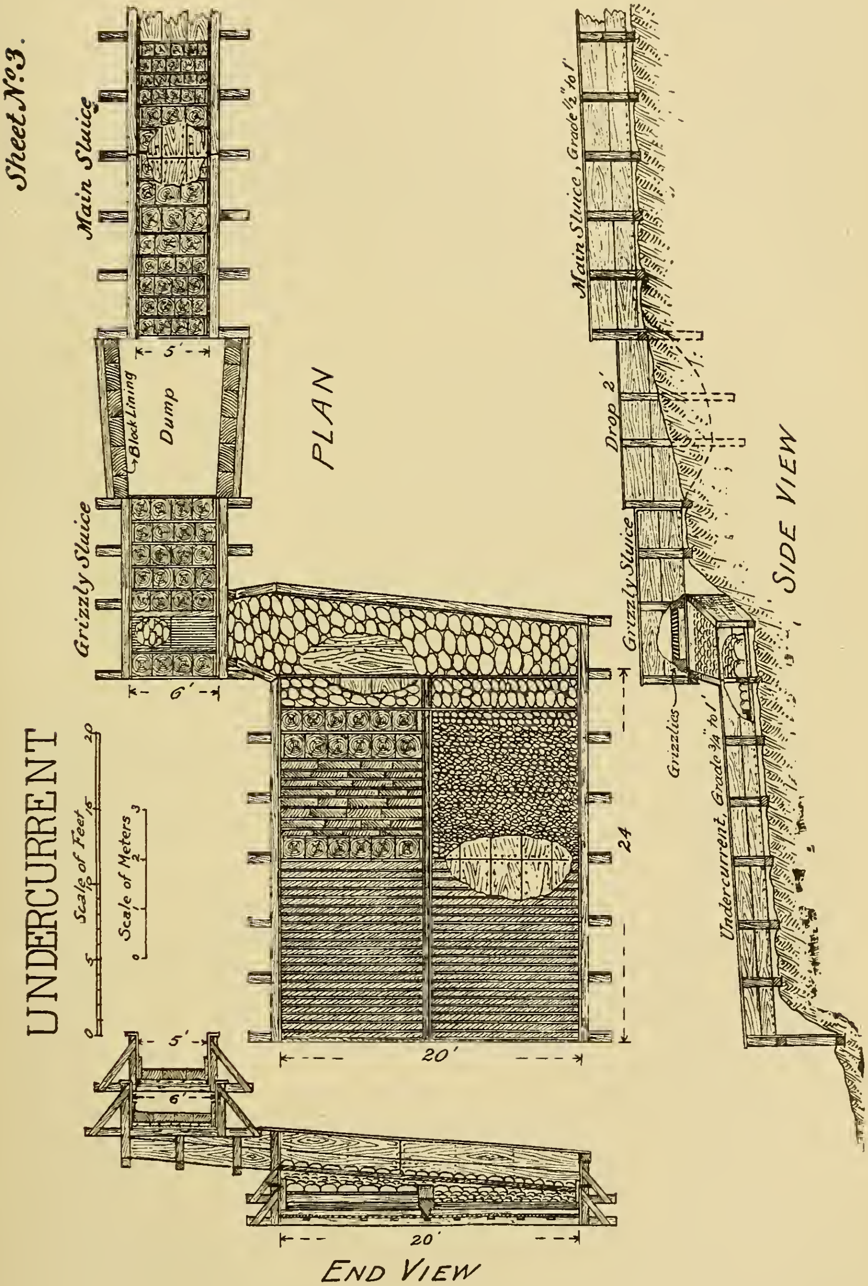
A clean-up is always required whenever the pavement is so worn by gutters that its surface becomes so uneven that it cannot be relaid to a sufficiently smooth surface without the use of additional paving material.

The cleaning-up is done by reducing the flow of the water to a very small quantity while the pavement is removing. The work is commenced at the upper end of the section to be cleaned up. As the pavement is removed, the fine material will be washed down slowly along the bared bottom of the sluice, leaving in its wake the separated gold, which is taken up in pans by scoops made for this purpose; the process is finished by panning the remaining sand from the gold, or amalgam, if quicksilver is used.

Undercurrents.

The use of these structural devices has been described before. They should be located wherever the hydraulic miner may deem them most effective. An ideal location for an undercurrent is created by placing a section of sluice 12 to 20 ft. long, and 1 ft. wider than the main sluice, at an elevation 2 ft. lower and about 10 ft. distant from the end of it. Near the lower end of this wide section of sluice, and at right angles across it, a set of steel bars, called grizzlies by the hydraulic miner, is laid. (See Sheet No. 3, and for details, Sheet No. 4.)

To prevent choking, these bars must be so placed that the space between them is wider at the bottom than at the top. Ordinary bars, 1 by 4 in., can be laid with a little care in this manner. These, to the number of from ten to twenty, are spaced


Sheet No. 3.
UNDERCURRENT
Main Sluice
5'
Block Lining
Dump
PLAN
Grizzly Sluice
6'
Scale of Feet
0
5
10
15
20
Scale of Meters
0
1
2
3
24
20'
5'
6'
20'
END VIEW
Main Sluice, Grade 1/2" to 1'
Drop 2'
Grizzly Sluice
Grizzlies
Undercurrent, Grade 3/4" to 1'
SIDE VIEW

from 1 to 2 in. apart, according to the character of the gravel and the volume of water used in the main sluice.

Steel bars, made for the purpose, with one edge thicker than the other, make good grizzlies. The construction and location of these details are shown on Sheet No. 3 and on Sheet No. 4.

Directly under these grizzlies, and parallel to them, a box from 2 to 4 ft. wide is provided, for the purpose of leading the water and fine material that has passed down between the grizzlies on to the undercurrent proper, which should be from three to five times as wide as the main sluice, 24 to 36 ft. long, and should have about 50 per cent. more grade than the main sluice.

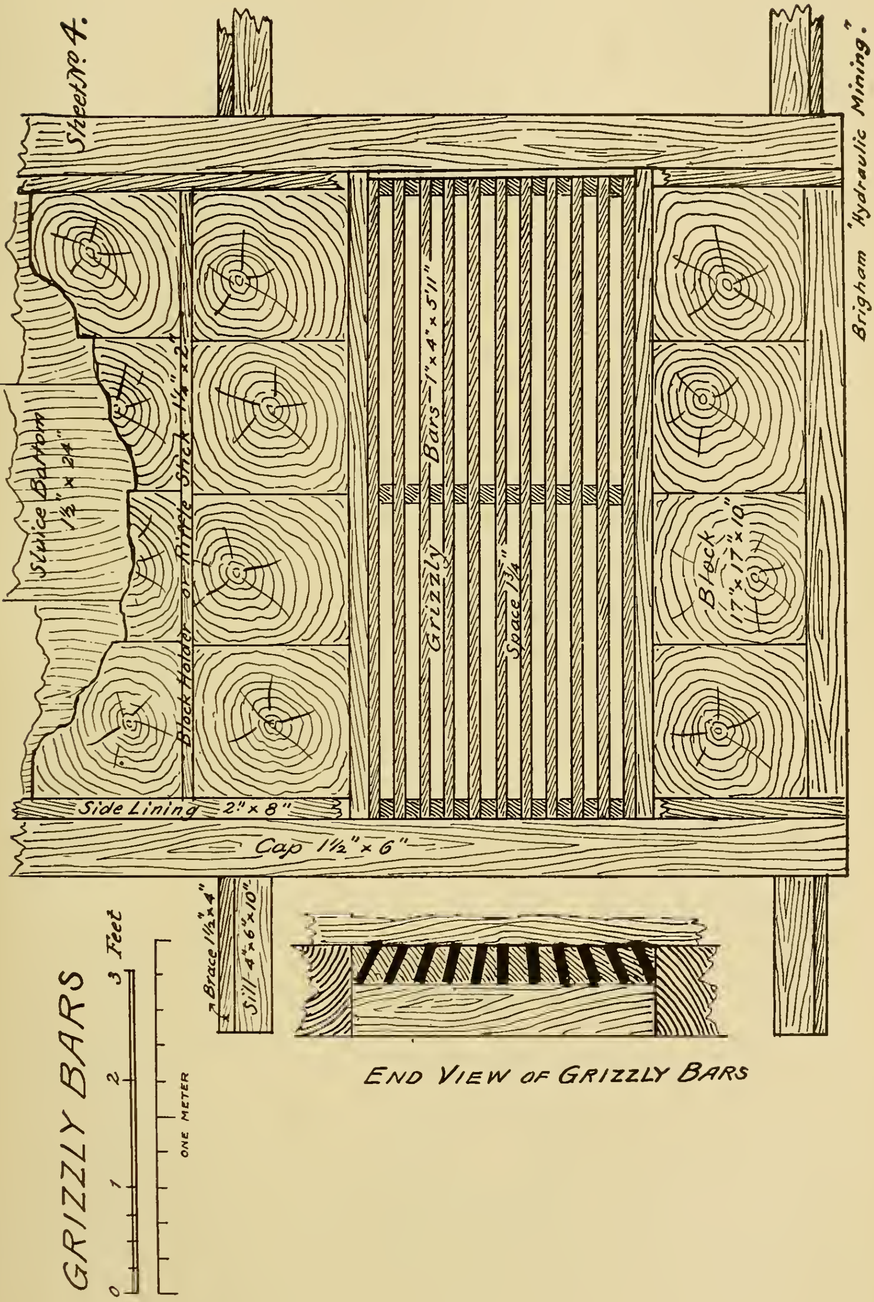
The number of grizzly bars, their distance apart and the width and grade of the undercurrent will depend upon the amount of water used in the main sluice and the character of the gravel washed; the larger the head of water and the finer the material, the greater the number of bars, and the narrower the space between them; also, the wider the undercurrent and the steeper the gradient. Where there is a very large amount of fine material, the undercurrent should have still greater width and grade than under ordinarily normal conditions. All the fine material, with sufficient water to run it over the undercurrent, must be allowed to pass through the grizzlies.

The purpose of the drop in grade of 2 ft. below the main sluice is to reduce the current while passing over the bars; this will allow the fine gold to settle more readily and pass through between them, and it will also increase the life of the bars and make them last much longer than if they were placed at the end of the main sluice.

A good pavement or riffle floor for an undercurrent may be made of strips 4 in. wide, 1½ in. to 4 in. thick, lined on top with ¼-in. steel plates held by countersunk nails. These riffles should be laid on edge, spaced 1¼ in. or 1½ in. apart, and may be laid either crosswise or longitudinally. Blocks also make a very good pavement.

If the richer portion of the gravel should be very hard or cemented, it is advisable to add more undercurrents if conditions will permit. To break up the cement, a high perpendicular drop is excellent.

Should it be necessary to extend the main sluice from its lower end, by reason of the filling of the dump with tailings that finally back up into it, or for some other reason, the policy of placing an undercurrent at such locality may be questionable, as


Sheet No. 4.
Brigham 'Hydraulic Mining.'
Sluice Bottom 1½" × 24"
Block Holder or Riffle Stick 1½" × 2"
Grizzly Bars—1" × 4" × 5'11"
Space 1¾"
Block 17" × 17" × 10"
Side Lining 2" × 8"
Cap 1½" × 6"
Brace 1½" × 4"
Sill 4" × 6" × 10"
GRIZZLY BARS
0
1
2
3 Feet
ONE METER
END VIEW OF GRIZZLY BARS

it is impossible to operate one midway in a sluice without sacrificing at least 5 ft. of the grade in order to get the water and the fine material that passes over the undercurrent back into the main sluice again.

Water Storage.

The necessity of receiving or distributing reservoirs has been referred to before. They furnish facilities to regulate the head of water for the giants, and whenever it may become necessary to turn off the water at the mine, the storage will be kept immediately on tap.

The capacity for these reservoirs must be determined by the daily quantity to be used by the mine; this again depends on so many other contingencies that one must consider them all before deciding upon the practical amount of storage.

In a previous chapter the principal governing elements have been touched upon already. The constructive details are matters of engineering that must be dealt with as they come up.

Pressure Box or Penstock.

A pressure box should be built at the head of the mine pipe line.

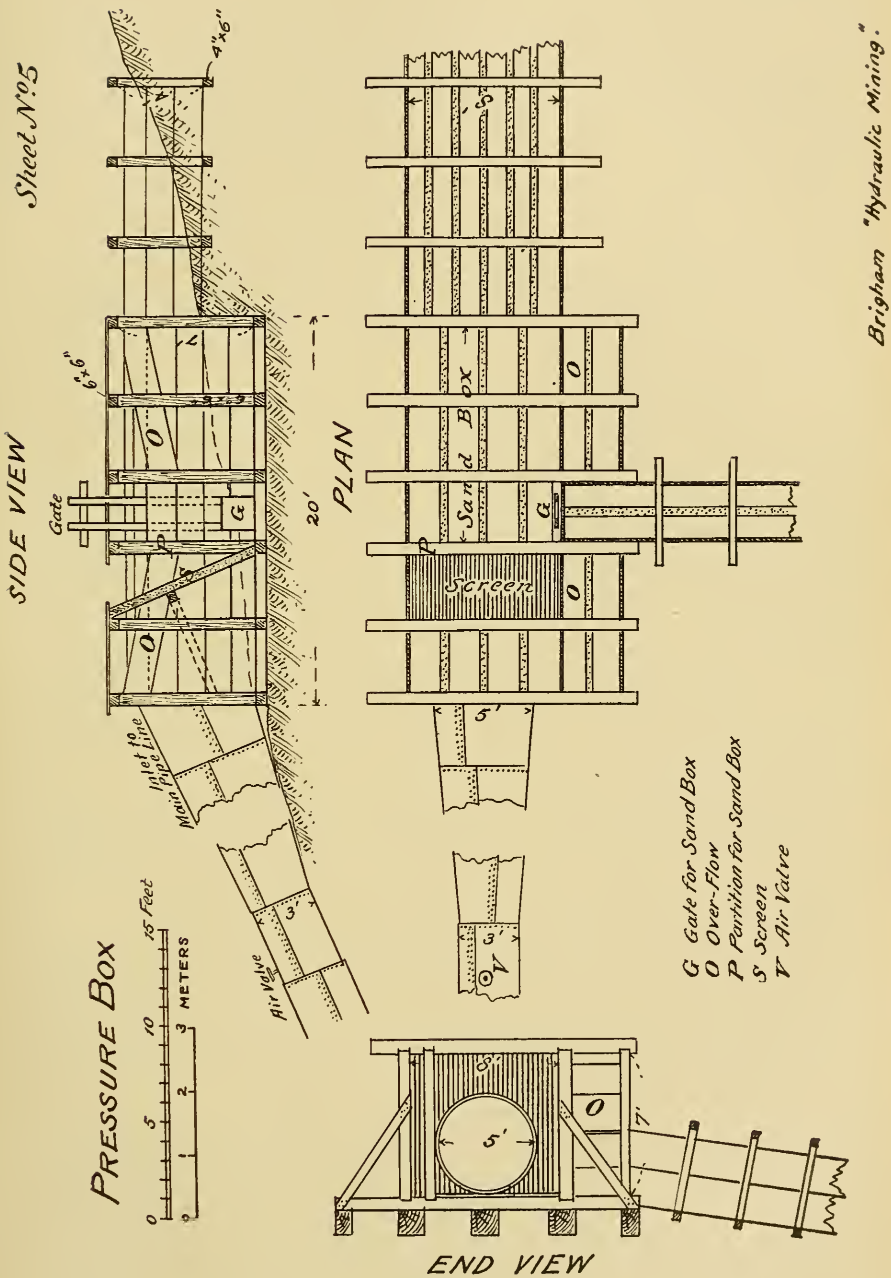
Sheet No. 5 shows a structure of this kind in plan and in view. It is more or less of a settling basin and strainer, intended to prevent sand and solids and also air from entering the pipe.

A screen is provided to catch sticks, limbs and other floating débris too large to pass through the nozzles, while a sand box of ample proportions holds the sand and other heavy material and prevents that from getting into the pipe.

A spillway is arranged on one side of the pressure box (see "*O*" on Sheet No. 5), to prevent any damage from the surplus water. This should be wide enough to take care of any possible surplus due to clogging of the screen or variation of the flow. If the water be taken out of the main ditch directly into the pressure box, and the ditch continue past it, a spillway is unnecessary.

The screen "*S*" on drawing should be fine enough to prevent anything from passing through it that may choke the nozzles, and should be so constructed that it can be readily cleared. It should also be strong enough to withstand the pressure in case it is fully choked with branches, leaves and other matter of this kind which is liable to occur during a windstorm.

The sand box should be given ample dimensions to fulfill its functions; it has a gate at the side to sluice out the sand and to


Sheet No. 5
SIDE VIEW
Gate
6"x6"
4"x6"
20'
Inlet to Main Pipe Line
Air Valve
PLAN
Sand Box
Screen
PRESSURE BOX
15 Feet
METERS
END VIEW
G Gate for Sand Box
O Over-Flow
P Partition for Sand Box
S Screen
V Air Valve
Brigham "Hydraulic Mining".

turn the water out of the pipe whenever it may be necessary to dry it.

If a larger head of water is used than can be accommodated by the sand gate, a waste-way must be provided near the bulkhead, so that the pipe may be dried quickly in case of accident, or in case there may be any necessity for changing the water suddenly.

Mine Pipe Line.

Where it is possible to bring all the water to one common and acceptable point to suit the conditions of head and locality, and in such a manner that one line may be made available for all the giants, a single line of ample capacity to convey all the required water is to be preferred.

A suitable gore or taper should be provided at the head of the pipe line, at the point of intake from the pressure box (see Sheet No. 5), and this should be of such dimensions that the water in entering the pipe is not retarded. The flatter the grade at the upper portion of the pipe line, the larger and the longer the gore that will be necessary. In any event, it should be of ample size not to create needless friction, which reduces the pressure at the giants.

The main pipe line should, if possible, be laid away from the ground to be washed, and preferably, also, on a downward grade for the entire distance, and long stretches of slack grade should be avoided, if practicable.

As the pipe approaches the vicinity where washing is to be done, suitable branches should be inserted where required until the end of the main line is reached, where a gore must be inserted, tapering to the size of the branches, or a fork provided for two branches. Each branch should have a gate or cut-off.

The branches and gates should be placed as near to the commencement of operations as practicable in order that the working area of the giants may be extended from time to time without the necessity of moving the branch pipes and gates, which is expensive and causes much delay.

If the face of the mine is very wide, and two or more giants are to be used at some distance from the main line and away from the vicinity of the other giants, it becomes advisable to make the branch of the same diameter as the main line — with a gate attached — and to extend this branch line to the neighborhood of the giants; this will eliminate much of the friction due to long reaches of the smaller branch pipes.

All turns, gates and gores should be substantially braced to withstand the pressure, and the whole line should be anchored at short intervals to prevent its creeping downhill by expansion and contraction due to changes of temperature.

Air valves of liberal area should be placed at different points along the line of the pipe wherever needed to prevent collapse from any sudden withdrawal of the water below. There should be one at every point where the grade increases materially, and one below each cut-off, if the pipe below it has considerable grade.

It is necessary to provide more than one pipe line:

First: Where the contour of the country will not permit a satisfactory site for a distributing reservoir, but where one at a lower altitude is available; or,

Second: Where a part of the water supply must be brought in a lower ditch system, too low for a satisfactory pressure and yet valuable; or,

Third: Where the deposit of gravel to be worked is so extended and isolated that a branch from the main line cannot well be utilized for it, then two or more lines will be necessary.

In the case of two available pressures at different heads, the higher pressure system should be used for the greater part of the cutting and the lower one for regulating the flow to the sluices of the gravel taken from the softer strata, or from the material that has caved under the force of the higher pressure.

Giants.

The number and size of the giants will be governed by the amount of water used, the width of the face of the gravel to be worked, the pressure of the water at the giants and the character of the gravel to be piped.

It is better to use as large giants as practicable, for much more can be accomplished with one large one than by running the same amount of water through two; also, the pay of one man is thereby saved.

The giants should be set as near the bank as safety from the falling bank will permit.

If more than one is to be utilized at one point, they must be placed so that they will command as much of the bank as possible, and be in such a position that two or more may work together advantageously in a combined attack towards one point.

Deflectors are indispensable for the larger sizes of giants. A deflector is comparable to a delicate steering apparatus; by its aid the stream may be guided from one direction towards an-

other. They are of two kinds: One consists of a short flexible coupling, inserted between the nozzle and the end of the discharge pipe; the other is a short section of pipe, a little larger than the nozzle, attached loosely to its end and projecting over the stream. Both of these deflectors turn on a gimbaled joint, free to move in any direction by an attached lever.

A light pressure against the lever in any direction bends the stream slightly; this, in turn, moves the discharge pipe, which follows it, as it were, until the stream strikes the desired point; the pressure is thereupon released, when the unmolested stream now becomes normal again and retains this direction.

Derricks and Overhead Trolleys.

If there are many large bowlders that have to be broken up in order to run them through the sluice, and if the grade of the sluice is light and the dump room scarce, it may be advisable to use overhead trolleys or derricks for handling them, if the conditions are favorable.

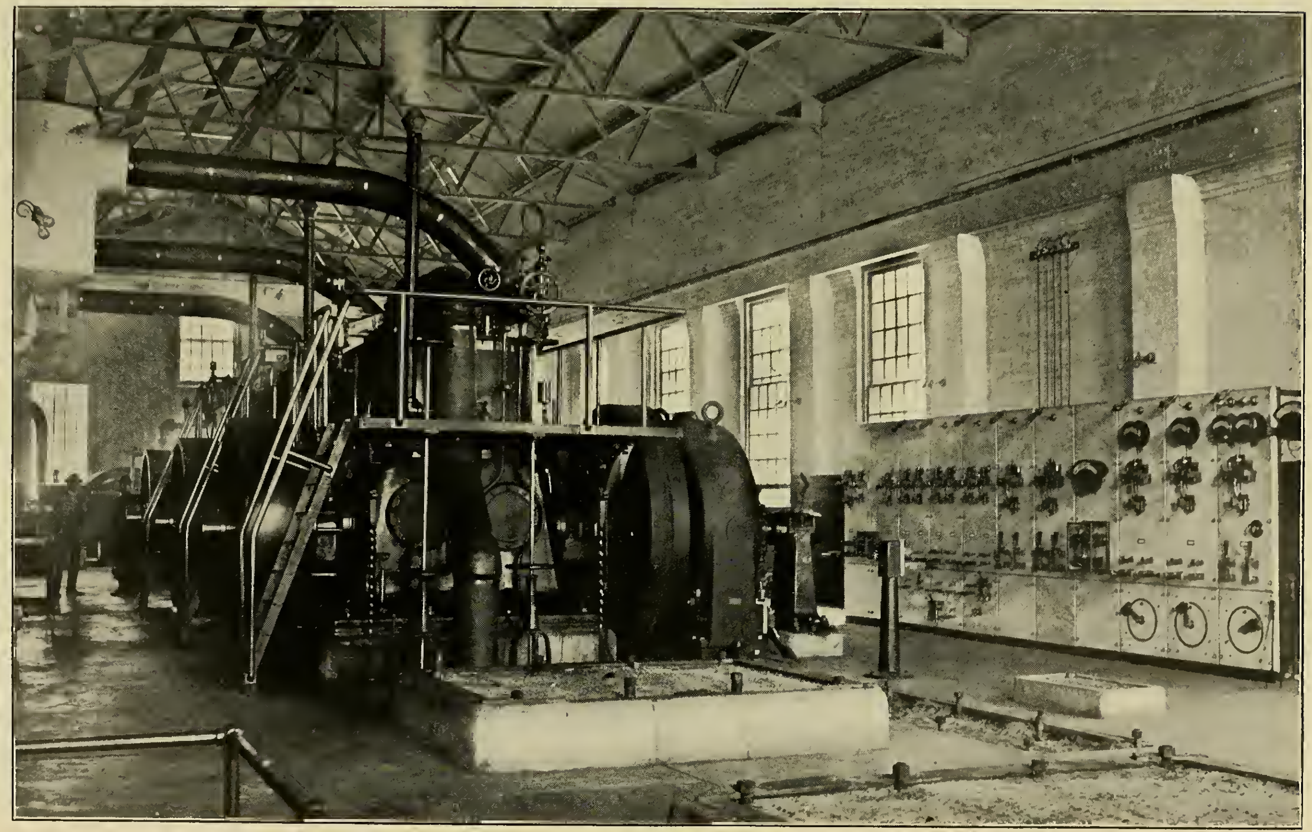
The derrick is an awkward and cumbersome thing to work around a hydraulic mine, especially if the bank is high and the pressure for giants light; it is necessary to have the derrick in rear of the giants, and this places it too far from its work, unless it has a very long mast and boom.

An overhead trolley is generally preferable, as this interferes little with the giants; and while its reach is restricted sidewise, it has unlimited range from the bowlder dump in the rear to the face of the mine; also, it seldom needs shifting as the working of the mine progresses.

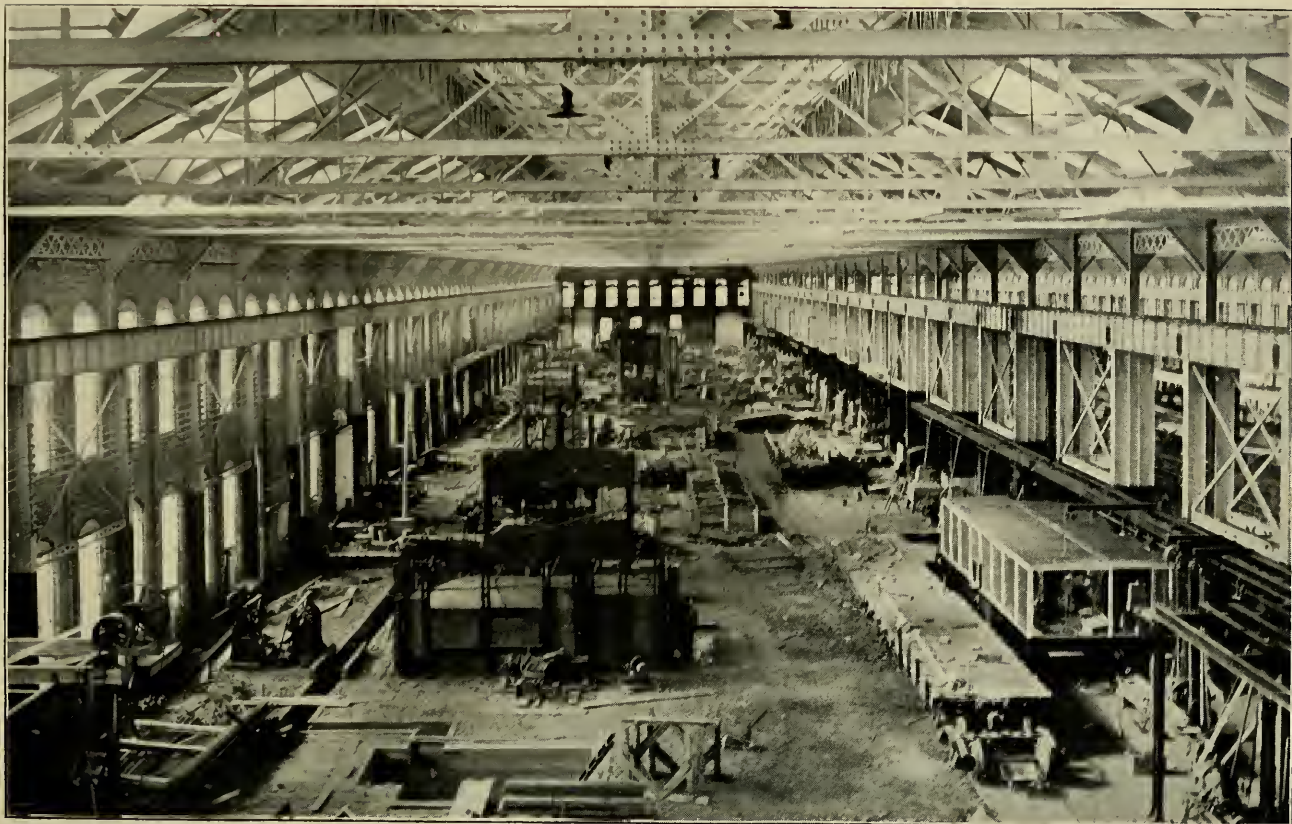
Where there are large numbers of bowlders requiring blasting in order to dispose of them through the sluice, and where the dump room is restricted, and where the conditions are favorable for utilizing derricks or overhead trolleys, it will be found much cheaper to dispose of these bowlders in this manner rather than run them through the sluice and choke up the dump.

Hydraulic Elevators.

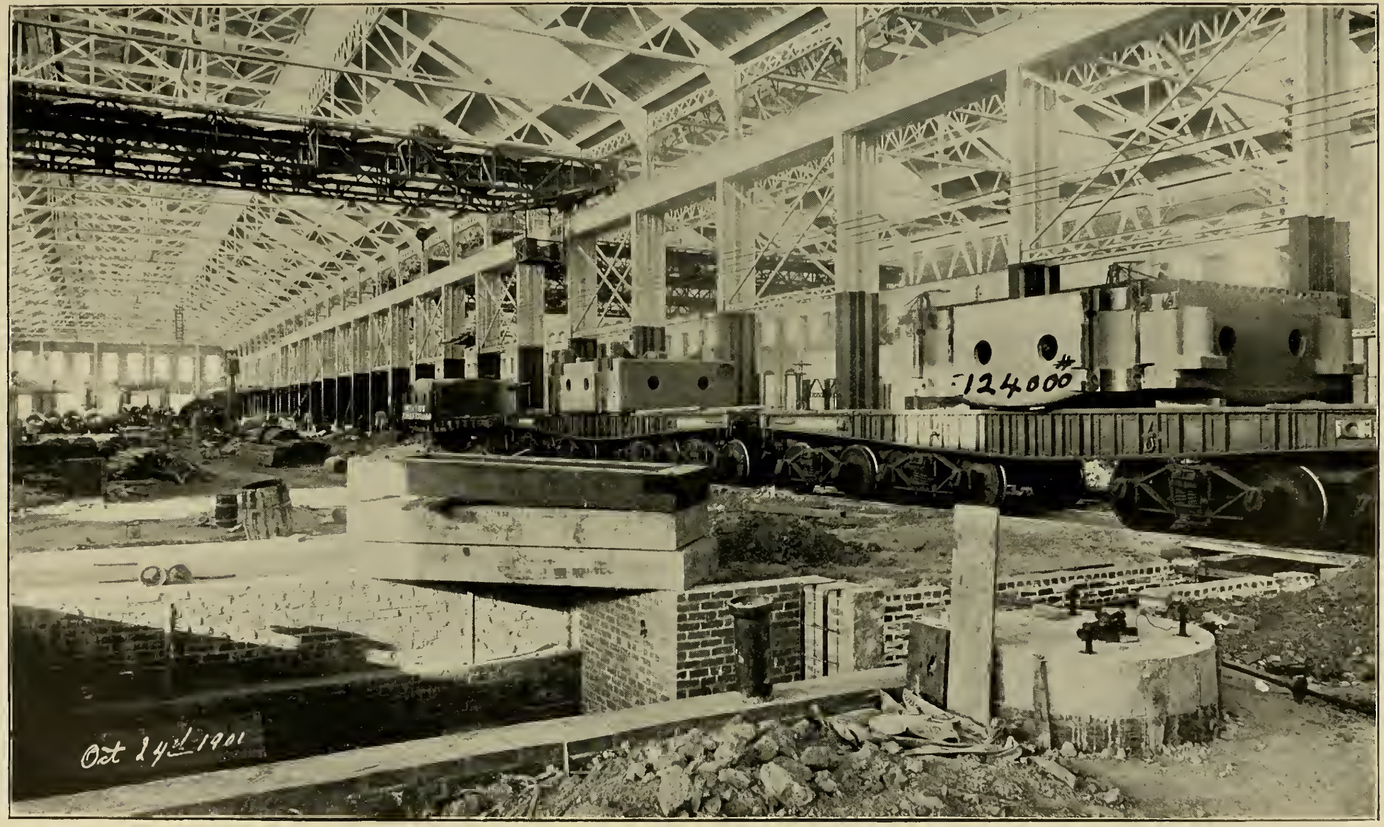
They may be used to good advantage at times, and in some cases the conditions are such that this is the only method by which hydraulic mining can be successfully prosecuted. In the case of valuable gravel deposits, free from quantities of large stones, pipe clay, stumps, etc., requiring hand removal, that are situated near or below the level of the surrounding country, and



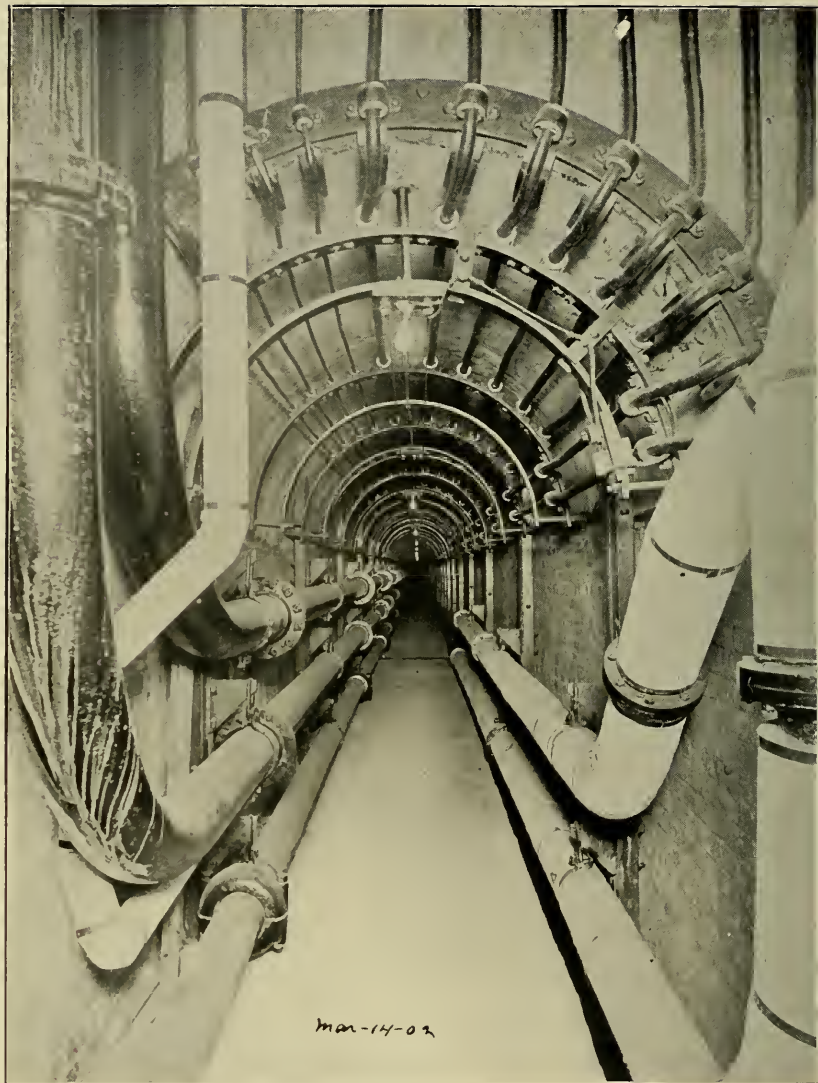
American Car and Foundry Company. Engine Room, Berwick, Penn.



American Car and Foundry Company. Main Car Shop, Berwick, Penn.



American Car and Foundry Company. Main Car Shop, Detroit.



AMERICAN CAR AND FOUNDRY COMPANY. PIPE TUNNEL, DETROIT.

with a large quantity of water under the required pressure at command, the hydraulic elevator becomes a necessity.

The elevators are placed near the head of the main sluice and at a lower elevation, depending upon the height necessary to raise the gravel.

A hydraulic elevator, so called, consists of a pipe of suitable dimensions to convey or lift the water and gravel from a pit, sunk below the bottom of the deposit to be worked, into the main sluice above. It is generally built at a small vertical angle; the top reaches into the main sluice; to its bottom in the pit is attached the elevator throat; a nozzle is placed a short distance below this, set in line with the center of the elevator pipe, and parallel to it, all for the purpose of forcing the gravel and water from the pit up into the head of the main sluice. The nozzle is connected to the main pipe line.

One or more giants may be utilized for washing the gravel from the mine into the elevator pit in a manner similar to ordinary hydraulic mining.

All stones, clay, stumps, etc., too large to pass through the throat of the elevator, must be removed before reaching the pit. The elevator must be run continuously while the mine is in operation, for the pit becomes flooded immediately, whenever the water is turned off from the elevator nozzle.

A giant under heavy pressure, placed at the lower end of the main sluice, may be used to great advantage in stacking or elevating the tailings wherever the dump room is ample in area but deficient in grade.

Any bowlders, stumps, etc., that will run through the sluice can be elevated by this process equally as well as the fine gravel.

This giant at the dump may be utilized at any time, whether the sluice be running or not, whenever there is a surplus of water, or whenever it may be turned off from the mine. Either the hydraulic elevator or the giant at the dump creates a larger grade for the main sluice, a matter that has been referred to before.

If there should be a depression in the bedrock of the mine below the grade of the sluice, or if the sluice as it extends ahead into the mine should pass over valuable deposits, this gravel could be elevated and forced up into the sluice in a manner similar to the elevation of the tailings at the dump.

This, of course, should be done after the top has been worked down to the sluice grade.

The depth from which gravel can be elevated by this process

depends upon the giant pressure. With a pressure of 300 ft. there should be no difficulty in forcing it up from a depth of 15 ft. or more.

Ditches.

The old hydraulic miner became an expert in the location and design of a ditch to convey the necessary water to meet his requirements. He was remarkably successful in overcoming difficulties of topography, and mechanical difficulties as well, and he usually overcame them without scientific instruments or scientific formulæ, guided alone by his keen sense of the practical and by his ever-resourceful mind.

Many of the old mining ditches in evidence to-day bear testimony to his skill, to his perseverance and to his audacity. Mining and ditch building were almost synonymous terms in California, and on the experience of the hydraulic miner much that we know to-day of the behavior of the flow of water in ditches and in pipes has been based. The investigations of Hamilton Smith are considered of great importance to-day and they have added no inconsiderable knowledge to what was at his time a rather barren field.

The irrigator has taken the ditch and flume in hand recently, but with him it is not so much a matter of overcoming physical obstacles as it is a problem involving a sufficiency of grade, volume and flow in the valleys, where the adequacy of the gradient becomes a subject of more serious consideration.

A ditch must convey the required quantity of water. To do so, it must have capacity and grade, or fall. These elements are interdependent and need to be placed in proper relation. The flow through a given cross-section of the ditch must be of a speed to permit the number of miner's inches to pass and yet not too swift to erode the material into which the ditch is cut. This matter has been referred to before.

While the hydraulic miner knew by experience how to arrange his fall, his grade and size, the engineer of to-day may have recourse to the elaborate formulæ that have been devised to help him. The Kutter formula and its modification by more recent hydraulicians, particularly Californians, furnishes him with the means to design ditches of proper capacity and gradient in any material. A few practical hints, however, by an old hydraulic miner will not be amiss.

In laying out the line of the ditch care should be taken to avoid any abrupt turn, unless this be absolutely unavoidable

In making a turn around a sharp point, the line should be carried into the hill somewhat, in order to insure a strong embankment.

In turning around such points, it may be desirable to raise the grade for the top of the ditch to correspond to the height of the permanent roadway along the ditch, thus leaving a solid embankment to the full height of the roadway.

The slope of the bank will be governed by the character of the ground along its course; the upper bank should be sloped back far enough so that the current cannot undermine it and cause slides or caves; accidents of this kind will occur during the rainy or flush water season, if they occur at all, causing bad breaks, and entailing great expense, loss of water and delay while repairing.

All trees liable to fall and damage the ditch ought to be cleared away. The surface below the ditch should be stripped of all brush, leaves, débris, etc., before commencing the excavation, in order that the material taken from the ditch and deposited on its lower bank may unite firmly with the undisturbed ground, making a solid and permanent bank after settlement, which will permit the miner to raise the water in the ditch later on, thereby increasing the capacity considerably.

After the ditch is excavated, the lower bank should be leveled down in such a manner as to leave a good roadway; care is to be taken that the elevation of this roadway be considerably above the grade line as a protection against breaks, when, for any reason, small obstructions should occur that may back the water slightly above the grade.

Flumes along the line of the ditch should be avoided as much as practicable, particularly if the water supply be partially or wholly cut off during the dry season; at such time the lumber will shrink and crack, damaging it more or less, and shortening its life considerably.

Where conditions are favorable, a double wall may be built, filled between its two faces with clay or suitable dirt, by which a permanent bank is secured; and while this will increase the original cost, the extra expense may be justifiable.

Even in quite hard bedrock, it may be perfectly reasonable to do considerable blasting in order to avoid a flume and to insure a permanent ditch.

The Flume.

This is so well known and has been used so extensively in

California that it seems almost needless to refer to it here. But however that may be, practice is gained by contact and experience, and errors are frequently committed in the earlier history of a work that might have been avoided if it had been possible to impart some of the results of those who had passed through similar experiences themselves.

The author in his long contact with many different types of flumes had under his immediate charge for several years one which so completely answered the requirements that it seems justifiable to call attention to it here.

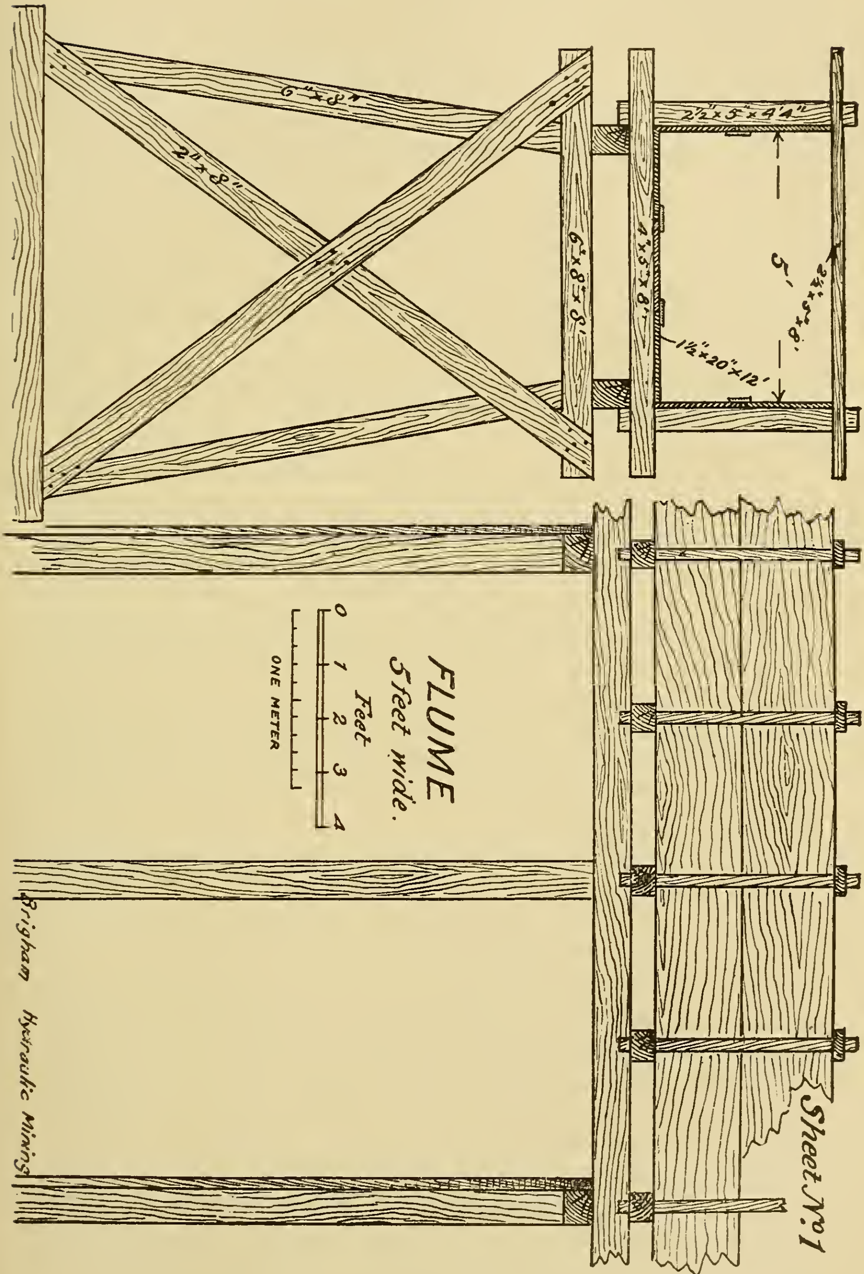
This flume was some 8 miles long, 4 ft. wide, 38 in. high, and lay on a steep hillside on a narrow bench that was graded just enough to afford a resting place for the inside of the flume; the outer side was held by props from the bank. This was the condition for nearly all of its length.

It was built of unselected yellow pine lumber, with $1\frac{1}{2}$-in. boards for bottoms and sides, 4 by 5 in. bottom ties, 6 ft. long; 2 by 5 in. top ties, 6 ft. long; and 2 by 4 in. posts, or standards, 4 ft. long; no braces; bottom and top ties mortised for the posts, which were unframed. (See Sheet No. 1, to which reference will be made frequently.)

This flume was in constant use for thirty years. The portion that rested but partially on the ground was kept in repair at small expense, and its use could have been continued at a nominal expense for several years longer had the market for its water still existed. Aside from renewals due to accidental causes, practically all of the flume that rested on the ground was still the original construction after its long use, and the greater part of it had not required the replacement of as much as a bottom tie in all that time.

It shows the possibility of a simple construction that one might not have ventured upon, preferring some more elaborate foundation at almost prohibitive cost. The risk proved the perfect practicability in the long and useful life of this simple flume, and it teaches us to place faith in the somewhat bolder design, if the best judgment has been brought forward in its location and alignment, and in the study of the topography to which the structure must be adapted.

A flume may be laid on an excavated bench on its sills, projecting over the bank more or less, in some manner as just described, or it may be erected on a partial trestle work for the support of the outer side. Gulches or deep ravines must be crossed on trestle bridges, as the illustration shows it. These


6"×8"
2"×8"
6"×8"×8'
4"×5"×8'
2½"×5"×4'4"
5'
2½"×5"×8'
1½"×20"×12'
FLUME
5 feet wide.
0 1 2 3 4
Feet
ONE METER
Sheet No. 1
Brigham Hydraulic Mining

may often become very formidable structures if there is no other alternative in making the crossing.

Short sections of flume should have the same area as the ditch, but long sections may be somewhat smaller, owing to the decreased friction of the water; it is questionable, however, whether a change of size is always justifiable, unless the reach of flume has considerable length, for the reason that it is inconvenient to keep various varieties and sizes of lumber in stock for repairs. If there is considerable repairing to be done, it is better to have only a few different sizes, thereby reducing the stock of lumber that would be required otherwise. It may be quite practicable to plan the size of the flume in such a way that the same sizes may answer for both sides and bottoms.

The size of the material for a conventional flume of the type under discussion may be obtained from the following general description:

Lumber of 1½ in. is very suitable for the bottom boards and the sides, where the depth of water does not exceed 3 ft.; if much deeper, 2-in. boards will be necessary, especially for the bottom.

For sills, or bottom ties, 4 by 5 in. pieces will answer for flumes up to a width of 4 ft. containing a 3-ft. depth of water; for a wider flume, 4 by 6 in. may become necessary; for a flume 10 ft. wide, with a 4-ft. depth of water, it will be well to make them 6 by 6.

For the top ties, or caps, take 2 by 5 in. pieces for a 5-ft. flume; 2½ by 6 in. will answer for one of 8 ft. where there is little snow. If much snow has to be provided against, they must be correspondingly heavier.

For standards, or uprights, use 2 by 4 in. lumber for a 2½-ft. depth of water; 2½ by 5 in. for a 3½-ft. depth; and 3 by 6 in. for water 4½ ft. deep. These sizes are all desirable as they need no framing, the bottom and top ties being mortised through. The standards, cut to proper length, are driven firmly into the bottom tie, which acts as a brace, eliminating the ordinary diagonal brace necessary where the standard is set into a gain in the top of the sill. Another advantage over the latter is, that as the flume becomes old and weak from decay, it is much more stable and also more easily repaired, and it will last longer than the flume in which the side ties are gained into the sills and caps.

In order to prevent the clear water from running over the sides of the flume abrupt turns are to be avoided as far as that can be done and as explained heretofore under "Sluices," where the object in view was that of preventing the sluice from choking.

Where a flume joins the ditch, especially at the upper end of the flume, a small gore should be inserted into one box-length, making it bell mouthed. This will prevent the water from backing up into the ditch, and it will have a tendency to prevent lumber, sticks and floatage from catching across its head. A similar case in the lower end of the flume, having a swift current, will prevent the ditch immediately below from undue erosion.

Waste-Ways.

Waste-ways for turning the water out of the ditch in case of accidents, oversupply from rains or melting snow, or other causes must be provided at intervals along the ditch. They should be placed at points where the escape of the waste water will not result in cutting away the ground below the ditch and endanger its safety.

If the ditch is in a cold country where large amounts of snow will collect in it faster than they can be run through it, or where snow is likely to fill up the ditch when the water is not running, which would have to be sluiced out later, the waste-ways should be at frequent intervals, for it is necessary to get the water out quickly and in time before they become clogged up and break.

All waste-ways should be so constructed that the entire flow can be quickly turned out, and they should be so located that the water may escape without endangering any part of the ditch. Some provision should also be made to keep the freshet water from ravines out of the ditch; if it be impracticable to place these waste-ways at or near the ravines, in order to use them for that purpose, other means must be found to prevent this serious inflow.

Concluding Remarks.

These notes on the subject of hydraulic mining have been collated not to furnish any text or data for the student, but rather to give the practical engineer who may come in contact with this sort of work some idea of the main guiding principles underlying the successful installation of a plant of this kind.

It has not been the idea to go into the processes and results of hydraulic mining proper, for that would require more time and space than the author had at his disposal; nor is it possible to give sufficient information of an extensive method that must be learned by daily contact to enable one to follow it as a profession.

This paper has been written for engineers and for those who

may follow hydraulic mining, with the end in view of placing certain practical knowledge at the immediate disposal of those who may be looking for it. This the author has attempted to do with some effort at system, although it will be admitted that he has frequently broken from one subject into another as these subjects become interlaced. However, it is hoped that he has made himself clear.

The illustrations that accompany this paper were made in detail to show without too much explanation the main constructions with which the hydraulic miner has to deal.

They consist of:

Sheet No. 1. Side elevation and section of a flume.

Sheet No. 2. Section through a sluice, showing the block system and the riffles.

Sheet No. 3. Plan and views of an undercurrent, showing constructive details.

Sheet No. 4. Plan and section of a set of grizzly bars showing the arrangement and location in the sluice.

Sheet No. 5. Plan and views of a penstock or pressure-box, showing constructive details.

Other Uses of the Hydraulic Method.

Hydraulic mining embraces two eminent branches of engineering, hydraulic or civil engineering, and mining engineering. Its field of separation has been confined to the mountains and its sole object has been the recovery of gold. Where nature has covered and hidden treasures by cyclopean power, man has brought them to light by the use of other herculean forces that he has been able to harness and to utilize according to his will.

But there is another field wherein the unfortunate miner may be dropped, that is, as far as gold seeking is concerned, and where the civil engineer may usurp his place, and that is in hydraulic excavations. Furnish water under sufficient pressure and favorable conditions and the process described will enable ius to remove mountains.

There are very great opportunities for the hydraulic method in the construction of earth dams and levees, in making the cuts and fills for railway embankments and in filling depressions by removing material from one locality and transporting it to another.

Where the conditions are favorable, an earth dam can be built more substantially and more economically by this method than by any other.

Millions of cubic yards of gravel have been displaced in California by hydraulic process, and the gold extracted therefrom, at a cost of less than one cent per cu. yard, aside from the expense of furnishing the water.

In the building of dams it is an open question whether a greater expense incurred by this method of depositing the material may not be justified, by reason of the greater security of a structure built up in this way. Its solid compactness and greater stability hold out every inducement to make use of hydraulic processes. This may be said with equal assurance of other embankments, because the settlement of such structures after completion by this method is practically *nil.*

Most localities where dams are contemplated will have a sufficient available supply of water for such purpose if it is pumped and the same water used continuously.

Where a sufficient pressure is obtainable, a hydraulic elevator may be installed to lift the earth from the reservoir bottom to the height of the lower portions of the embankment, leaving but a comparatively small part of the upper work to be completed by another process.

In the building of levees the hydraulic method is particularly well adapted, because it is not only economical to use it, but it will also make an extremely stable and solid embankment, one that cannot be made equally stout and firm by any other process. The conditions are generally favorable to utilize it, too.

It requires some skill and experience to obtain the best there is in hydraulic work to build dikes and levees, but in the consideration of the great amount of such work to be done, there is every reason why the civil engineer should acquire a practical knowledge of this useful method.

The author may have more to say on this particular part of the subject at some future time.

DISCUSSION.

Mr. W. W. Waggoner (*by letter*). — It has been a pleasure to read the paper upon hydraulic mining by Mr. H. A. Brigham, Member Technical Society. The author is one of our ablest hydraulic miners; he has given many valuable hints to those who may use this means of moving material, not to be found in the textbooks. The paper should be preserved as a valuable work of reference.

Gravel mining was the great industry that brought California into prominence. During its development it brought

forth many able hydraulic engineers, who invented methods and appliances that have been found valuable in other branches of constructive work. A phase of hydraulic mining is now used on river banks to prepare them for revetment, for railway embankments and for dam building. By this means a watertight bulkhead may be built to any practicable height.

The use of riveted wrought-iron pipe, although first used to displace canvas hose, has now a wide application in conveying fluids.

The rock-fill dam is another novel method of dam construction that is now recognized as standard. It is to be regretted that the name of the engineer who developed this method of moving material is lost to history. His work stands out more boldly when it is considered that gold was discovered in 1848. The year 1849 saw the first influx of gold-seekers. In 1855 our reliant pioneers had found the best gold deposits and had recognized the needs of the water supply. One of the earliest companies, with French capital, under the management of Benoit Fauchere, now spelled "Faucherie," built the dam at the locality known as French Lake, during the time from 1855 to 1858. It is probably the oldest structure of its kind in the State. In the primitive condition of the times (without roadways, without Portland cement), the designer broke away from all precedent and built his rock-filled dam 68 ft. high, with a water slope of one on one, and a downstream slope of ten on one. The stone on its faces was carefully laid. To make it watertight, a plank skin was used. There were no sawmills, but the planks were got out by whipsawing; they were fastened to the ribbing by tree-nails. On the flat slope the water holds the planking in place with the same force that would take it away. This plank face has been replaced several times. With a future impervious concrete face it will stand for centuries as a monument to its unknown designer who broke away from all precedent and builded better than he knew. So must we depart from the conventional in order to solve the problem presented by the author.

It is with some reluctance that I attempt the task assigned me by our Society, — to open a discussion upon the problem of the future recovery of the $90 000 000 of treasure locked up within the great gravel deposits.

It is now twenty-four years since the Sawyer decision was rendered in the celebrated suit entitled Edwards Woodruff *vs.* North Bloomfield Gravel Mining Company et al., which resulted

in the closing down of the hydraulic mines. Since that date but little has been done towards the solution of the problem, and but little could be done on account of the ill feeling that such litigation and its attending losses are sure to produce. The lines of Rossiter W. Raymond in describing an apex mine lawsuit are very applicable:

> "No matter now which party lost —
> It took the mine to pay the cost;
> And all the famous men who saw,
> Beheld with mingled pride and awe
> What science breeds when crossed with law."

The mine has been doomed already, and it looks very much as if the farm would have to go, too.

Most of the men who were prominent in the hydraulic mining industry have passed away since. This is also largely true of the prominent valley men who took part in the dispute. The men who will meet this problem are of the succeeding generation, and they should be able to enter upon its solution without the rancor that injected itself into the past attempts. The problem is local; it is of no use to go to distant parts of the world to obtain talent and to search for men to do something concerning which they have no experience and little knowledge of the principles applied. On the contrary, it will result in a definite plan if the engineers of the different interests get together as a jury, as it were, and come to an agreement. It is fitting that some attempt should be made towards the solution of this problem by the Technical Society; its members are prominent in the State, and some of them who took part in the litigation could now lend great aid, with their riper experience, in the consummation of a plan that would mean so much to the welfare of the Country.

The problem, as far as the mines are concerned, is comparatively simple, and were it not for the complications already existing in the valley, that resulted from the operations of the mines during the last half century, a matter which will be dwelt upon later on, the solution would not be difficult.

After the injunctions, and when the mine owners became aware that if they were to operate their mines extensively they would have to impound their tailings, it was recognized that the cost of restraint would be a serious addition to their operative expenses. For that reason, with various arguments, attempt has been made to get the general government to bear a part of the expense, but so far without avail. To-day the mines are

closed down, the companies are disorganized, the miners are scattered or in other pursuits, much of the water that was used for mining is diverted to other industries at a better profit, and the mines themselves, even to the pits in many cases, are being reforested with a thick growth of trees. To resume hydraulic mining operations is a question of dollars and cents. The deposits to be worked are all known; so are approximately their values. If they are worked, it must be with the distinct understanding that their débris is impounded. For many mines this will be a permanent injunction, inasmuch as they could not work at present prices and with the demand for water. For those that would pay, storage would have to be provided. This is a question of capacity, with due regard for the "facilities of dump" that our author dwells upon, and in addition, one of location and of the effect of débris upon existing interests.

In the last twenty-four years there has been a wonderful development in other lines. The use of electric power, irrigation and the dredge mining industry have come to the front. These can be developed to a marked extent in the area adjacent to and available for the impounding of débris, at a reasonable cost and as part of the plan for the resumption of mining operations, thereby reducing the cost to the mines.

Take the Yuba River, for example. On its watershed are the greatest gravel deposits that have been the scenes of the largest mining operations. This river is at present, without any mining, the worst offender as far as deteriorating the navigable rivers is concerned. Dams can be built upon that river at many practicable sites. They should be of stone and, needless to say, of a permanent character. The type may be (where a proper foundation is available) that of a masonry dam for the storage of water, or it may be formed by blasting down great masses of rock from the adjoining cliffs and throwing them into the canyon, forming a bar as it were, and thereby raising the plane of the river. The winter floods will take a portion of it away each season and deposit the rock farther down stream. But working upon the principle by which the rivers were filled by the early mining, that is, that of dumping more rock into them than the floods could carry away, the dam can be raised to a great height. The blasts may be so arranged that when the final height has been attained a wasteway may be built that will carry any coming flood around the dam, thereby insuring the stability of the structure for all time.

From the crest of the dam the water — amounting at present in the low season to 500 second-feet — may be taken around the hills to an available site for the installation of a large electric power plant, and thence led around the foothills of Yuba County for irrigation purposes. By taking the entire low-water flow out of the river, eight miles of its channel will become available for dredging purposes for a long period of each year. This ground is estimated to have a value of $20 000 000. Future hydraulic mining operations will require additional storage of the flood waters and thereby add to the material wealth. The sites for such dams are in mountain canyons that have no particular value at present, and they can be filled to a great depth by the outlined methods. If these dams had been built years ago much of the débris now in the lower rivers would have been kept out of them and would lie away from its present resting place. Such structures would also tend to impound much of the natural erosion of the mountains that now reaches the rivers below. Were such works to be constructed, capital would have to be secured to reopen the mines, rebuild the water-supply systems and to bear a share of the expense of dam building. It is not conducive to the investment of new capital in this enterprise if the present valley conditions are once fully recognized.

It should not be overlooked that such an investment will be constantly harassed by certain interests, until relief is brought to the valley from the accumulations of the old débris in the non-navigable streams, for which this new capital could not be held responsible in any wise. The investors will naturally consider it enough of a burden to impound their own débris and that of natural erosion.

Now for the valley phase of the problem. The Yuba River, after it leaves the mountains, spreads out to a width of nearly three miles between the levees, with a grade of from 3.5 to 19 ft. per mile. It is filled with débris from the past operations of the mines, ranging from fine silt to cobblestones. It is known to be 31 ft. deep at its mouth, near Marysville, and it is estimated to be 100 ft. deep at a locality known as the Barrier Sites, 15 miles upstream. In one place the débris is 14 ft. above the adjacent land. This deposit has been variously estimated by different engineers. It was placed at 700 000 000 cubic yards by those who knew the quantities sent down. Over this deposit great floods flow every few years. I have seen the Yuba at flood time flowing to the width of one fourth of a mile, 10 ft. deep in the

shallow water, with a velocity of 14 ft. per second in slack water.

When the mines were in operation, twenty-four years ago, the water in flood spread over the entire area and only the fine silt was carried to the mouth; the gravel was deposited higher upstream. Since the mines have been closed and the supply of mining débris cut off, the river has been eroding the gravel in the mountain canyons until they are now practically clean of débris, and it has redeposited this upon the great layers. Now, and for some years past, the floods have been attacking the deposit by cutting deep channels; the material so eroded is carried into the Feather River; at the same time gravel is brought down from its upper reaches and deposited below. From all appearances the cobbles will also be represented. This is one of Nature's laws of restoring the base level after the period of artificial filling ceases. From a mining standpoint it is a magnificent example of ground sluicing. The effects are disastrous. The heavy material deposited upon the bed of the Feather River, with only a grade of about 1.5 ft. per mile, causes a rise in the water-table of the surrounding country. From this cause alone thousands of acres of valuable land are destroyed in Sutter County by seepage water. It causes the levees to be raised higher each year. . To illustrate conditions, let us take the high-water records at Marysville. During the period of extensive mining, and later during the illicit stage, only in one instance, that of December 24, 1884, did the high water reach 17 ft. 1 in. Since then, under channel building conditions, we have the following flood heights upon the Yuba River:

May 27, 1895	15 ft.	10 in.
January 18, 1896	18 ft.	5 in.
February 6, 1897	16 ft.	3 in.
February 7, 1898	12 ft.	1 in.
March 25, 1899	18 ft.	5 in.
January 3, 1900	18 ft.	0 in.
February 2, 1901	19 ft.	0 in.
February 26, 1902	16 ft.	11 in.
March 31, 1903	19 ft.	4 in.
February 25, 1904	20 ft.	0 in.
January 23, 1905	17 ft.	9 in.
January 19, 1906	21 ft.	9 in.
February 2, 1907	22 ft.	4 in.

On March 19, 1907, the gage read 24 ft. 4 in., and a much higher record would have been made had not a levee broken on

the Sutter side. The above shows a deplorable condition in what should be a prosperous farming region. What is to be done with the deposits of débris in the non-navigable streams, adjacent to the navigable rivers, lies within the province of the engineers representing the valley interests. They have serious problems to solve in preventing the overflow of the land. Efforts have been made to get government aid, but so far without success, for the government limits its work to maintaining low-water navigation. What is wanted now by all concerned is a cure, not palliative treatment.

It must be evident to all that a solution of the river problem is not possible without taking care of the débris now adjacent to the navigable rivers. The débris may be treated in one of two ways.

First, by keeping it out of the rivers; this will be complying physically with the intent of the decisions of the courts, and if works were built with a liberal factor of safety, the mines could operate without further restriction. The condition of the rivers would be improving while the other features of the valley problem were receiving attention.

Second, by finding a new resting place for the débris.

The various factors that make up the " facilities for a dump," as in mining, have to be considered. From a mining viewpoint, hundreds of millions of cubic yards of material will have to be handled. The work may be done either by channel building and sending the material handicapped with the decreasing river grades to the bays, or by dredging and stacking the material upon adjacent land and destroying this with the sand and the gravel. It occurs to a miner that the cheapest method must be that of keeping the material out of the rivers altogether. By so doing a " community of interests " will exist between the farmer and the miner, and stronger reasons may be given why the government should aid in the work.

It must be recognized that the débris problem is one that, in time, will affect all the rivers of the country. One hundred years from now there may be 250 000 000 people within the United States. Much of the mountain land now covered with timber will be, of necessity, cleared and in cultivation. The rains will erode the soil as now, and the flow of mud and sand will be increased. The river channels that are now, according to reports, deteriorating, will be more deeply filled and navigation largely destroyed. Already investigations are being made by the federal government, looking to the conservation of natural

resources. It will be found that the conservation of the soil by keeping it on the land and not in the rivers will be profitable both for the individual and the government. The work should begin now, and California offers peculiar advantages for the undertaking and should be the scene of the first work.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by January 15, 1909, for publication in a subsequent number of the JOURNAL.]

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THE RECTANGULAR SYSTEM OF SURVEYING.

BY W. A. TRUESDELL, HONORARY MEMBER OF THE CIVIL ENGINEERS' SOCIETY OF ST. PAUL.

[Read before the Society October 12, 1908.]

OVER four years ago a paper on this subject was read before this society and afterwards printed in the ASSOCIATION JOURNAL (April, 1904). Unavoidably it was somewhat brief and incomplete and contained opinions that will bear modification. The true origin of the rectangular system was not considered. Some of the men connected with the earliest surveys were given undue prominence, while others did not receive sufficient mention. This paper is offered as a supplement or revised edition to the first one, with the hope that it will give additional information on a subject that was never generally well understood.

No writer has ever given this subject any attention at length. There have been many allusions to it in historical works and writings, but in every instance the origin was either unknown or shrouded in mystery. Some eight or ten different persons have been credited with the authorship of the system, from De Witte, a Dutch surveyor, to President Washington, who in reality was very much opposed to the ordinance of 1785. Professor Davies taught that Colonel Mansfield originated and adopted the system in 1802 expressly for the wild lands of the West, and another writer has found the origin in the far-off Roman Empire.

The origin and history of the rectangular system of surveying is an open book with no mystery about it. No man in particular

was the originator. It was the result of growth and development founded on the fundamental principles of self government, formulated into a law after a long and acrimonious sectional controversy and put into practice because necessity required it.

Any one who attempts to investigate this subject will be greatly surprised at the scarcity of material. The government records and archives contain nothing whatever. No information can be obtained from the General Land Office, or from those states where the records of the earliest surveys are deposited. There is probably not a letter that Jared Mansfield ever wrote while surveyor-general now in print. There is a mass of papers, letters and other documents, especially the papers of the Old Congress, all in manuscript, now in the vaults at Washington, but it is inaccessible. Until this is unearthed and placed in the hands of a capable person a complete and correct history of the rectangular system cannot be written.

The Ordinance of 1785 in the Continental Congress.

The record commences in 1784. On May 7 of that year an "ordinance for ascertaining the mode of locating and disposal of lands in the western territory, and for other purposes," was reported by a committee and read for a first time. This committee was, Thomas Jefferson, of Virginia; Hugh Williamson, of North Carolina; David Howell, of Rhode Island; Elbridge Gerry of Massachusetts, and Jacob Read, of South Carolina.

On May 18, the report was called for but not considered, only one state voting aye.

About this date Jefferson was commissioned by Congress as minister plenipotentiary to assist Franklin and Adams in negotiating treaties of commerce with European countries. He joined his associates in Paris the following July and had nothing further to do with the legislation of this law. The ordinance was not considered again until the next March, when Congress was in session in New York.

On March 16, 1785, the report of Jefferson's committee was taken up for a second reading and ordered to be recommitted to a committee composed of one member from each state. This committee was made up of Long, King, Howell, Johnson, Livingston, Stewart, Gardner, Henry, Grayson, Bull, Williamson and Houston.

On April 14, Grayson, of Virginia, submitted for this committee a newly written report entitled, "An ordinance for ascer-

taining the mode of disposing of lands in the western territory," which was ordered read for a first time. When first submitted, it provided among other things for the division of land into townships seven miles square. This ordinance was brought up and considered almost daily from April 20 to May 3, when it was amended from "seven miles square" to "six miles square." The amendment was made by Grayson, and seconded by Monroe of the same state. Twelve states voted, all in favor except New York. The ordinance was then considered on six different days until May 20, when it was read for a third time and passed. The final vote is not given. (Journal of Congress, Volume 4.)

This is the recorded history of the famous ordinance of 1785. Its primary object was the raising of revenue, yet so many were the conflicting sectional opinions between the New England and the Virginia members, and so great was the inertness of Congress, that it required a year to enact the measure into a law. It was passed only after great effort, and was then a result of compromises. Grayson, writing to Timothy Pickering, says: "Since I arrived here I have been busily engaged in assisting about passing an ordinance for the disposal of territory. I think there has been as much said and written about it as would fill forty volumes and yet we seem far from a conclusion." (Grayson to Pickering, April 27, 1785.)

The ordinance of 1785 was the origin by law of the rectangular system of public land surveying and the first legislation on the subject. Nothing officially is known beyond this act. The records show that Jefferson at first and Grayson, later, were the most active in its formulation, but the many different interests that developed during its consideration, and how they were finally reconciled and compromised, the numerous arguments that were urged for and against the measure, are now difficult to determine.

The ordinance reported May 7, 1784, was most thoroughly prepared and written wholly by Jefferson's own hand. There is reason to believe that he was the principal, if not the sole author. It has always been believed, but erroneously, that this was the first suggestion ever made to divide the wild lands of the West into square forms. The suggestion in itself has been considered a wonderful creative idea, and Jefferson has been credited with this first stage of the system which was finally made a law. Although he was a man who always had ideas and opinions of his own, he could not have been ignorant of General Putnam's letter to Washington in the previous year or of Hutchins' plan of

frontier settlements in 1764. Furthermore, unlike all other Virginians, he was a great admirer of the New England towns and had said that " they had proved themselves the wisest invention ever devised by man for the perfect exercise of self-government and for its preservation." He had repeatedly urged the same system in Virginia.

There is no unusually great invention or conception in the square form provision of the ordinance, neither is there any necessity of speculating about its origin. The physical features of the western country, wild, vacant and prairie, would naturally suggest such a plan. No matter how irregular any subdivision might be inaugurated, it would eventually work itself into regularity with latitudinal and longitudinal boundaries. It will be shown later that this was actually done in southern Vermont, thirty-five years before the land ordinance was written.

That part of Jefferson's report which related to the surveys contained the following provisions:

1. The territory to be divided into hundreds of ten geographical miles square, each mile containing 6 086 feet, by lines to be run and marked due north and south, and others crossing these at right angles. The hundreds to be subdivided into lots one mile square, each of 850 acres, by marked lines running in a like manner north and south, and others crossing them at right angles.

2. Surveyors, to be appointed by Congress or a committee of the states, to divide these lands into hundreds under direction of the register. Lines to be measured with a chain and plainly marked by chops or marks on trees and exactly described on a plat, whereon shall be noted in their proper distances all water courses, mountains and other remarkable and permanent things over or near which such lines shall pass.

3. Nine townships to be assigned to each surveyor, who shall divide each hundred in his district into lots. Lines of the lots shall be distinguished by a single mark on a tree, those of a hundred by three marks.

4. Describes the manner of numbering the lots from one to one hundred.

5. Surveyors to pay due and constant attention to the variation of the magnetic meridian, marking on every plat what was the variation at the time of running the lines thereon.

6. A register to be appointed by Congress for each state, to keep an office in, and to reside within, the state, to receive all plats semi-annually and to deliver them to the secretary of

Congress, he to have power to suspend any surveyor for cause.

In the ten miles square hundred we can see the trend of Jefferson's ideas. He was committed to the decimal system. He had recently proposed the division of the entire Northwest territory into ten states of square forms, either one hundred or one hundred and fifty miles in size, and had planned and secured the adoption of our present system of coinage.

The report submitted on April 14, 1785, was written by Grayson, of Virginia. It was made up by him from the many conflicting opinions and was urged through Congress by his effort. In a great measure it was copied from Jefferson's report of the previous year, though with some changes, the principal ones being the seven miles square township and the appointment of a geographer. Grayson uses the words "township" and "section" for the first time. Jefferson's hundreds were to be divided into lots on the ground, and the method of numbering through the hundred was specified. Grayson's townships were divided into sections on paper only, without any described manner of numbering. The manner of running the lines and marking on trees was the same in both ordinances, and very deficient. It is evident that so far no practical surveyor had been consulted.

Those provisions which related specially to the surveys were very small portions of the ordinance. Each one described the country to be surveyed and contained much more which is irrelevant here, covering in detail the sale of the land and how it should be paid for; designating the officers who should transact that part of the business; also several provisions about reserving certain lands and moneys for payment of officers' and soldiers' claims; for school funds and for other purposes; transmitting township plats; reserving a part of all gold, silver, lead and copper mines; making out and delivering deeds and the forms of deeds.

The ordinance as finally passed differed somewhat, through amendments, from the one first submitted. The townships are six miles square, lots are used instead of sections and there are no 320-acre divisions. There is no subdivision into lots on the ground, and no specified manner of numbering the lots. The same method of running and marking the lines is prescribed, except that in running the external lines of a township the surveyors shall, at the interval of every mile, mark the corners of the lots which are adjacent, always designating the same in a different

manner from those of the township. Every alternate township to be sold by lots, all others to be sold entire.

From the time this ordinance was recommitted on March 16, until its final passage, a period of two months, the Eastern people were arrayed against the Southern on almost every provision of the measure. In fact, they were contending for the extension of their favorite principle of self-government, and it was only by meeting each other half way in a spirit of compromise that any agreement was possible.

That part of the ordinance which provides for the division of land into square form, and which is, in fact, the whole substance of the rectangular system of surveying, was due entirely to the determined stand taken by the delegates from New England. (Monroe to Madison, May, 1785.) That our entire country from the original thirteen states to the Pacific Ocean has been covered by what is no more or less than the New England township system is due wholly to their efforts. If this law had not been enacted and executed at the opportune time, the Virginia plan, with its attendant evils, would have prevailed. The ordinance was actually opposed long after its enactment. Madison in writing to Washington says: "Although the township plan of surveys had been adopted in May, 1785, the controversy between that system as the favorite of the Eastern people, and that of indiscriminate location, the Virginia plan, was still kept up. The states which had land of their own for sale were not hearty in bringing the federal lands into the market." (Madison to Washington, April 16, 1787.)

After Grayson's report had been considered one month, James Monroe, a Virginia delegate, wrote to Madison: "The original report admitted of the sale only of tracts containing thirty thousand acres called townships; this was adhered to with great obstinacy by the Eastern men and as firmly opposed by the Southern. At length, however, the Eastern people gave up this point, at least so far as to meet on middle ground. As it now stands it is to be surveyed into townships containing about twenty-six thousand acres each, each township marked on the plat into lots one mile square, and one half the county to be sold only in townships, and the other into lots." (Monroe to Madison, May, 1785.) That is, the New England members favored the township plan; the Southern members were in favor of indiscriminate location.

Grayson, who appears to have had charge of the bill, also wrote to Madison in about the same strain. "I shall give you

what I have in the manner the New England delegates wish to sell the continental land." "The matter is still under consideration, and other alterations will no doubt take effect." "An amendment is now before the House for making the townships six miles square." "Whether this will be carried out or not I cannot tell, the Eastern people being amazingly attached to their own custom to have everything regulated according to their own pleasure." (Grayson to Madison, May 1, 1785.)

It is interesting to know some of the arguments the New England members advanced in their zealous support of this ordinance. We have access to a few which Grayson gives in a letter to Washington. In fact, all we know of the inside history of this important piece of legislation is from several letters of Grayson's to different public men of that time.

1. "There certainly must be a difference in the value of the lands in the different parts of the country, and this difference cannot be ascertained without an actual survey at first."

2. "Because the Eastern states, where lands are more equally divided than in any other part of the continent, were generally settled in that manner."

3. "The idea of a township, with prospects of support for religion and education, would be an inducement for neighbors of the same religious sentiments to confederate for the purpose of settling together."

4. "The Southern method would defeat this end by introducing the idea of indiscriminate locations, which would have a tendency to destroy all these inducements to emigration."

5. "The exemption from controversy on account of boundaries for all time."

6. "The right to form governments for themselves would induce emigrants from all parts of the world and insure a settlement of the country in the most rapid manner."

7. "The expense and delay would be too great to divide the territory into fractional parts by actual survey."

8. "The method of laying out the same into squares is attended with the least possible expense, there being only two sides of a square to run in almost all cases."

9. "It supersedes the necessity of courts for the determination of disputes."

10. "It excludes all formalities of warrants, entries, locations, returns and caveats, as the first and last process is a deed."

What did the Virginia delegates have to offer against this array of argument? Nothing especially, except their antagonism to the New England township system. They claimed that the sale of the lands would be greatly delayed until they could be correctly measured, but their great cry was first, last and always, indiscriminate location. They insisted on the rule which would

give the most full scope to the roving emigrant, a policy which was carried out to the letter in the settlement of the Virginia Military Tract in Ohio, and in the states of Kentucky and Tennessee.

The Six-Mile Square Township.

The six-mile township comprised about the whole of the system of public land surveying when the law was first enacted. Principal meridians, base lines and standard parallels are improvements which were introduced later by different men connected with the surveys, and have since been sanctioned by law.

There has been a great amount of speculation about the origin of this township,—where it came from and why that particular size and who is responsible for its adoption in the ordinance of 1785. It has generally been considered an offhand creation, especially for the vacant lands of the Western territory, and proposed either by Capt. Thomas Hutchins or Gen. Rufus Putnam at the time the land ordinance was written. Like all other prevailing ideas and opinions about the origin of the rectangular system, this is not true, for it is a matter of history that the six-mile square township had its birth and grew to maturity in another part of the country generations before it was transplanted to the wilds of Ohio.

It is now known that Gen. Rufus Putnam was the first to suggest the six-mile township, which he did in a letter to Washington in 1783, in which he says that the tract of country between the Ohio River and Lake Erie, which is petitioned for, is large enough to contain seven hundred and fifty-six townships of " six miles square," and proposes to have it divided " by townships six miles square, or six by twelve, or six by eighteen, to be divided by the proprietors to six miles square, that being the standard on which they wish all calculations to be made." (" Life and Journal of Manasseh Cutler," Vol. 1, p. 167.)

But this idea was not original with General Putnam. He was only advocating a custom with which he had been familiar a long time. His letter to Washington might not have had a wide circulation, but that he exerted his great influence with the delegates from his own state is at least probable. He was a very prominent man, a practical surveyor and he appears to have been very much confirmed in his opinion how the Western lands should be subdivided. His prominence in the history of the early surveys and their origin is well established.

It is immaterial whether General Putnam was interested in

the land ordinance or not. The New England delegates did not require any outside influence, for they evidently had opinions of their own on the subject which must have been identical with Putnam's and derived from the same source. That they were familiar with the townships and town governments of their respective states goes without saying. That they were instrumental in reducing the seven-mile township to six miles is also certain. They were not satisfied with Jefferson's hundred, or Grayson's seven-mile tract, and as they were determined to have everything according to their own regulations, they insisted upon the New England method. Grayson, in his letter to Madison, says about as much, and it would be inferred from Monroe's letter of later date, though they were obliged to vote for other amendments which they did not favor. It was these men, and principally Rufus King, who, by way of argument, persuasion and compromise, inserted the six-mile township clause in the ordinance.

To find the real origin of the six-mile township we must go beyond Putnam's letter to Washington, beyond the ordinance of 1785; in fact, to colonial times, and we shall find that it is no more or less than a counterpart of those seats of local self-government that were planted in the New England colonies when first settled. (*Engineering News*, May 4, 1904.) All these states, with the exception of Maine, had been entirely covered with townships before the land ordinance became a law. They had become a firmly-established and vital principle whose great benefits and superiority could not be questioned even in other portions of the country where the system had not been adopted. During the formation of these townships, covering a period of at least one hundred and twenty-five years, they eventually developed into a uniform size if not a regular form, a tract of country about six miles square or its equivalent, which was considered to be the most suitable for the requirements of a well-appointed town.

In those parts of the New England states first occupied, the towns are of all sizes, shapes and directions, occasioned probably by topographical features of the country and local circumstances in settlement. They suggest a rude beginning, which they really were, before any well-defined plan had become necessary. Their boundaries were often broken and irregular, as if to inclose different groups of settlements or desirable pieces of land, or perhaps riparian benefits. Prof. John Fiske says that in the earliest settlements these tracts were generally anywhere from six to ten miles in either dimension, but some of them were much smaller.

As people moved westward a change for the better is noticeable, approaching more to regularity, as if the country was being uniformly settled. In the districts occupied latest, there is a marked improvement over all other portions of the country that is at once conspicuous. The towns approach nearer to a square or rectangular form, they resemble each other more in size and shape. They appear to have been laid out with a systematic attempt to make them neither too large nor too small, as if it had become the confirmed opinion that three miles or so was far enough for any resident to travel to his church or town meeting.

This is the result of a settled policy which had its origin in Massachusetts when people began to move westward from the first settlements on the coast. It was an effort to establish a standard size for the tracts of land that were being granted and occupied. This policy dates from 1634, when the General Court began making grants to individuals and communities for plantations which were settled as colonies by people from the older towns or by newly-arrived emigrants from England. The grants were generally made upon petition and after a legislative committee had viewed the land and reported. At a later date when the grants had become quite frequent, a permanent committee was appointed for this purpose. The boundaries were always surveyed and care taken to preserve the lines. The town outlines were generally controlled by local features and circumstances, but the size was always specified and never very large. The great requisite was desirable farming land, which often accounts for irregular forms. The Connecticut and Merrimac rivers also were controlling influences in many of the outlines, and the river was often a boundary. The formation and settlement of a plantation was always considered a matter of the utmost importance and was generally managed by the older town where the emigrants had lived.

" There were cases where tracts of eight miles square were granted, as at Groton, Mendon and Newbury. On the other hand, some of the older towns were quite small, but in general a tract six miles square or its equivalent was thought the best for a plantation." (" Johns Hopkins Studies," Vol. 4, p. 32.) Furthermore, it was a fixed policy to settle the unoccupied territory in a uniform manner and to grant a company of emigrants just what was required for agricultural interests and no more.

Perhaps the first mention on record of a piece of land for a town of this size was in 1652, when about twenty persons from Concord petitioned the General Court for a grant of land border-

ing on the Merrimac River, "to run by said river and to make up a quantity of six miles square." The grant was made of that size but in a rectangular form and incorporated as Chelmsford.

Probably the first grant ever made in a tract of this size with a square form was in 1656. Certain petitioners, inhabitants of Sudbury, asked for a grant to colonize. The General Court made the grant and specified six miles square. This was incorporated by the name Marlborough, and was probably the original regulation township. Another early instance was at Brookfield. The General Court made a grant in 1660 and specified six miles square. There was a similar one at Ashfield in 1690 and one at Northfield in 1672 where a grant was made of "six miles square in area, the length not to exceed eight miles." (Historical Collections of Massachusetts, Barber.)

This practice was continued as long as there was territory to give away, but as it was a rule with the General Court not to prejudice any plantation previously made, the six-mile grant was not always possible, but its equivalent in area was adhered to in a rectangular form. In fact, there are a large number of towns in Massachusetts which are not square, where the original grant distinctly called for a square. Here were people talking about tracts of land six miles square for settlement in a wild country and a legislature dividing its unoccupied territory into divisions of that particular size and form for town governments, over a century and a quarter before the ordinance of 1785 was enacted.

The following is an illustration of the New England plan for granting territory and forming towns. It gives the drift of ideas prevailing at that date. It was for a company of sixty neighbors who proposed to settle a new tract of country together.

"June 17, 1732, the General Court of Massachusetts granted six miles square for a township to be laid out in a regular form by a surveyor and chainmen, under oath. The said lands by them to be settled on the following conditions: That they, within the space of five years, settle and have on the spot sixty families (the settlers to be none but natives of New England), each settler to build a good and convenient dwelling house, of one story high, eighteen feet square at least, and clear and bring to, four acres fit for improvement, and three acres more well stocked with English grass; and also lay out three shares in the town (each share to be one sixty-third of the town), one share for the first settled minister, one for the ministry, and one for the school; and also build a convenient meeting house and settle a learned and orthodox minister within the time aforesaid." ("History of Hardwicke," p. 23.)

This was fifty-three years before the land ordinance, and the practice was continued still later. In the few years following grants of this size were very frequent, about twenty being made in three years, among which were four townships for building a wagon road, four for military services and one for the use of the Stockbridge Indians. Ten grants were also made in one body and sold at public auction in 1762.

Coming down to the latest date, we find that in 1781 the General Court of Massachusetts appointed a legislative committee to consider the disposal of all unappropriated lands in the Province of Maine, and in July, 1783, the county of York in that province was directed to be surveyed into townships six miles square. (JOURNAL OF ENGINEERING SOCIETIES, Vol. 3.)

These illustrations are taken from the earliest and the latest periods of town making, in a country where the work was brought to perfection. They are by no means all that could be enumerated, but they are sufficient to show where our standard townships come from.

At the time of the Revolutionary Was there were about two hundred towns in Massachusetts; probably fifty or more of them had been made equal to six miles square by grants or .acts of incorporation. In Connecticut there were forty-six either six miles in both length and breadth or that amount in area. ("Historical Collections of Connecticut," Barber.) They are generally rectangular or trapezoidal in outline, although many approach closely to a square, with boundaries unusually straight and tending towards meridians and parallels.

It can be readily understood why public opinion concentrated on the six-mile size. It fulfilled in the best manner the purposes that a town was made for, which was a colony that must have its town meeting for self-government, its school and church. A four-mile neighborhood would be smaller than need be, one eight or ten miles in extent too large and inconvenient. The ideas of that early date in respect to the size of a town to suit its requirements are just as true to-day.

The townships planted in Massachusetts were only preliminary to what followed later in other parts of New England. The same system was extended to New Hampshire early in the eighteenth century by Massachusetts before the boundary line between the two colonies was established. Perhaps one of the first was at Londonderry about 1718, followed by others in the same vicinity. A continuous line of towns was also laid out from the Merrimac River to the Connecticut in 1726, all six miles square.

At the same time the province of New Hampshire was making grants on its own authority, and when Governor Wentworth came into office, he made it a special business to cover the country as rapidly as possible, and in 1761 he granted eighteen towns in one body bordering on the Connecticut River. Not all the towns in New Hampshire are of this size, a few are larger, and there are quite a number that would average only five miles in length and breadth, but the six-mile size was generally specified. In 1733 the town of Boscawen was granted and incorporated, a tract six and one-half miles long and six and a quarter wide, to ninety-one petitioners. From a very old history of the town of Bath the following is taken: "Like all other towns in this vicinity Bath was originally calculated to contain six miles square. Its length, however, exceeds its breadth by a quarter of a mile." (Massachusetts Historical Collections, Vol. 3, p. 105.)

In the north part of the state the towns are well laid off with regular boundaries and inclining very much to north and south and east and west directions. In the central part, which is a mountain and lake region, and also in the south, they are generally square but lie to all points of the compass. The six-mile square provision in these grants referred more to the size than the outline.

It was in Vermont that the regulation township reached its highest and most extensive development, for it was a fixed rule to adhere to that special size and form whether any rugged, natural features of the country interfered or not. In 1749 the first one was surveyed and granted at Bennington, by Governor Wentworth, of New Hampshire, to people of Portsmouth, for settlement. It will probably be interesting to land surveyors, especially in the West, to know that this was the first standard township ever surveyed in the United States with boundaries north and south and east and west.

With this township as a starting point he made grants very frequently during the following years, until 1764, when more than one half of the present state had been covered. Their number was one hundred and thirty-eight. All of them were made as nearly as practicable six miles square and were granted on the same conditions as the Massachusetts township. As a method of working in one part of the country, a line was measured along the Connecticut River in winter on the ice, for sixty miles, and a tree marked on each bank every six miles for corners from which the townships were laid off. In this manner three lines of towns

were surveyed on each side of the river, and sixty of them in Vermont were granted to colonists in one year.

When Vermont was made an independent state government in 1777, the legislature commenced at once to grant all unappropriated lands in the state, and at the time disposed of a number of townships. In 1780 charters were issued for about fifty more new townships, all on petition, and six miles square. All of these grants provided for the New England system of town governments, with sixty families to a town and sixty-five shares in each town, five of which were to be public rights, for the support of a college, for a county grammar school, for an English school, for the first settled minister and for the ministry. ("Vermont Settlers and New York Land Speculators," Benton.) In the north part of Vermont the towns lay diagonally towards the meridians, occasioned by working northwestward from the Connecticut River, but in the south, for about forty or fifty miles north of the south boundary, the townships were surveyed by meridians and parallels resembling very much the work in a western state. It was here, in fact, that the rectangular system was first put into practice. Gov. Benning Wentworth, of New Hampshire, anticipated the land ordinance of 1785 by thirty-five years. From 1749 to 1780, a period of thirty-one years, there were over two hundred townships planted in Vermont, every one of them six miles square. At the time the land ordinance was made a law there must have been at least four hundred in these northeastern states.

The New England delegates had grown up to these conditions and they carried their ideas with them to the Continental Congress. The legislation over the ordinance of 1785 was a conflict of opinions and embraced a wide scope, religious, political and sectional, but principally it was the town against the shire, and the New England plan prevailed.

Early Surveys and Methods.

One year after the enactment of the ordinance the first surveys were commenced in what is now Ohio, and for nineteen years they were confined entirely to that state.

The history of these surveys is generally well understood and there is no necessity of repeating it here. Ohio was a sort of experimental ground, divided into a large number of tracts, purchases, reserves, congressional lands and Indian territory, where many independent interests and various new and untried policies had to be exploited. As a result, before the surveys had

proceeded very far, it was found that they were being loosely and irregularly executed, and for good reasons. The country was rough, wild and difficult to operate in. There was always great danger from hostile Indians. The system, crude at first, had not received its finishing improvements. It was not until an entirely new territory was ready to be opened up that Surveyor-General Mansfield was able to introduce any refinement of method and regularity into the work. This was done in what is now Indiana.

While the ordinance was under consideration, and during the survey of the different tracts in Ohio, there were a number of methods proposed and used for subdividing townships and numbering the sections.

Grayson's report did not explicitly state how the forty-nine sections should be marked on the township plat, and the law as finally adopted contained the same omission. A section of the final ordinance reads: "The lots shall be numbered from one to thirty-six, always beginning the succeeding range of the lots with the number next to that with which the preceding one concluded." This would admit of sixteen different methods of numbering a township. It is probable that this part of the work was intended to be left to the judgment of the geographer. At any rate, Hutchins pursued a plan of his own and in the first townships surveyed in the Seven Ranges he commenced with number one at the southeast corner and numbered north through each range of lots to number thirty-six in the northwest corner.

He appears also to have had ideas of his own about marking the lines, for instead of following the incomplete method of the law, which was merely chops on trees, he set a post at every mile and marked a witness tree on each side. The act of May 18, 1796, changed Hutchins' numbering to the present method.

During the first four years of surveys in the Military Bounty Tract, townships were made five miles square, divided into quarters and numbered from one to four. After this, fifty of those quarters which had not been sold were divided into lots of one hundred acres each. All the remaining lands in the tract were subdivided into "sections."

The Western Reserve was surveyed under direction of Surveyor Seth Pease, from 1796 to 1806. The work was very much superior to the congressional surveys made at the same time. The range lines were called principal meridians and were all run due north. Townships were five miles square and divided into quarter towns of 4 000 acres each.

While in office, Surveyor-General Mansfield was asked for

his opinion about the expediency of dividing all sections into quarters at the time the section lines were run. He reported unfavorably, principally on account of the additional expense, but said that in the Indiana surveys all quarter corners had been built on section lines when they were surveyed.

The law of May 18, 1796, introduced an improvement in the work of running section and township lines. It provided among other things for the marking on trees, one in each section, near to the corner, the number of the section town and range. The law of May 10, 1800, originated the present method of running the section lines north and east, and for throwing the excess or deficiency, as the case may be, on the north and west lines of quarter sections. Some practical surveyor must have been responsible for this innovation. It is the opinion of those who have been engaged on public land surveys that it would be a great improvement in subdividing a township to divide it into quarters at first, and then complete each quarter by the above method.

Waynes' treaty line was an important and controlling function in the Ohio surveys. It separated the Congress lands from Indian territory and limited the extent of the surveys on the West until 1805. It was surveyed in 1798 by Israel Ludlow.

In the country south of the Military Tract and west of the Ohio Purchase the surveys became very much distorted, and to correct them a new meridian was run from the Ohio River northward between ranges 17 and 18. All the irregular work on the east was closed up to this line, and new and correct surveys commenced on the west, which were continued to the Scioto River. In some cases a quarter section on the east was as large as a whole section on the west. This line was not strictly a true meridian, but was intended to be parallel to all other range lines in that part of the country. Its correct direction is about four and one-half degrees east of north.

The survey of the country between the Great and Little Miami rivers, or what was intended at first to be Symmes Purchase, was a curious proceeding, but it is interesting because it was here that a meridian and base line were run and called by those names, although ranges and townships were not numbered from them.

From the most southerly point of land on the Ohio River between the two Miami rivers, a line was run due north, by Israel Ludlow, to the Great Miami, a distance of about twenty miles, marked with corners at every mile and called a first meridian.

At six miles a line was run east to the Little Miami and one west to the Great Miami, marked with corners at intervals of a mile and called a base line. From these corners one mile apart, lines were run north by magnetic needle, fifteen miles from the base line. The east and west lines were not run. A line was then run north six miles without any marking, across range number three. Then an east and west line between the two Miami rivers marked every mile and called a second base, which was the south boundary of the fourth range. Then lines north from this second base to the north line of the sixth range; then another east and west line from one river to the other. ("History of Butler County, Ohio," p. 24.)

In this manner the surveys were continued for some distance northward. This was in 1788 and 1789. Afterwards most of these lands reverted back to the federal government and were resurveyed under General Putnam's direction during 1802 and before by somewhat the same method. The townships present a strange appearance on the map. Ranges are numbered northward from the Ohio River, and towns east from the Great Miami, a system directly opposite to that of the others in Ohio.

The survey of the country between the Great Miami River and the Greenville treaty line was a mismanaged work, yet there was one great improvement made over what had been done before which must have influenced Mansfield in the Indiana system. As a first step the Indian boundary on the west was run in 1798, and in the fall of the same year, a line due north from the mouth of the Great Miami River to the same treaty line near Fort Recovery, a distance of about ninety miles. Both of these lines were surveyed by Israel Ludlow, who was the ablest and most prominent of the Ohio surveyors. The last line was expressly for a principal meridian and was used to number ranges from east and west. This was two years before Indiana was made a territory, and four years before Ohio was admitted as a state, but it had been known since the ordinance of 1787 that such a line would be the eastern boundary of the second state formed out of the Northwest Territory. This was called the First Principal Meridian, after Mansfield had established the second in Indiana. This line was extended north of Fort Recovery in 1817 as a state boundary.

In the south part of this tract, near the Ohio River, the surveyors ran the township lines east and west, then the range lines south, and subdivided the country. North of this they ran the range lines in the eastern part of the tract at first, and later towards the west, closing on the principal meridian, contrary to

a well-conducted survey. Townships were numbered north from the Ohio and Miami rivers, making a number in a range on the east in some cases six and twelve miles north of the like number in a range on the west. Of course, General Putnam had his reasons for working in this manner, nevertheless, it will always appear strange that he did not have the originality to establish a base line for this tract.

There was one provision in the ordinance of 1785 that Surveyor-General Putnam did not like. The north and south lines were to be run by the true meridian, but it appears that he disregarded the rule in the surveys made under his direction. On March 10, 1798, he directed a letter to Congress in which he asked for the repeal of that part of the law and gave several reasons why it was necessary.

"It would be exceedingly inconvenient and embarrassing, if not altogether impracticable, for the deputy surveyor to run lines in that manner.

"There is a difference in the variation of the magnetic needle at different places and at no great distance from each other in the Northwest Territory so that a compass rectified or adjusted to the true meridian in one place will not cut that meridian in all parts of the country or in the tract to be surveyed.

"It would take very frequent observations to discover whether lines are being run according to the true meridian or not.

"In the surveys of the lands west of the Seven Ranges to the Scioto River, and in the Military Tract, the north and south lines were run as nearly as possible parallel to the west boundary line of the Seven Ranges, and all the compasses of the surveyors were rectified to one meridian corresponding to that boundary line.

"He had instructed two of his surveyors, on whose ability he could depend, to ascertain the variation of the needle from the true meridian in various parts of their districts, but they both failed in the attempt by reason of fogs, clouds, etc.

"An attempt to survey by the true meridian will be impossible to carry through in an uniform manner, and the lines would not correspond so well with each other as if surveyed by the meridian adopted for the Military Tract."

This letter was referred to a committee who reported that it would be improper to repeal that part of the law mentioned. General Putnam was afterwards removed from office on account of poorly executed surveys, and this indiscreet letter might have had something to do with it. His great fault was that he made no effort to run lines by the true meridian, and follow the requirements of the law. (Public Lands, Vol. 1, p. 73.)

Mansfield's Record as Surveyor-General.

Jared Mansfield was the first person ever appointed to an office under the government on account of his scientific attainments. His arrival at Marietta in the fall of 1803 was none too early, for during the few years previous the public surveys had been going from bad to worse, and it was time for some effort at correction. There had been too little regard for a true meridian, too much inattention to magnetic variation, and perhaps considerable general carelessness. As a result, the surveys had become greatly distorted, and if they had been continued in that manner, the rectangular system would have been doomed to an early failure. That an effort was finally made to improve the work is entirely to the credit of President Jefferson.

Mansfield had little to do with public surveys in Ohio. General Putnam, while in office, had pushed the work energetically, and at the end of 1803 about all the country south and east of Wayne's Treaty line had been surveyed at least into townships. Mansfield's work was confined principally to the country between the Western Reserve and the Military Tract and in subdividing townships in different parts of the state.

In 1805 he moved his office to Cincinnati and in the same summer he went to Indiana to establish the Second Principal Meridian. The Vincennes Tract, so-called, had been surveyed the year before under his direction. This was a piece of land about forty miles wide by seventy-five in length, ceded by the Indians in 1803, the only settled portion of the territory. The base line was first run its whole length, about one hundred miles, passing nearly midway through the country to be subdivided. From this initial line ranges and townships were laid off, north and south, so that by the end of 1804 nearly the whole tract had been subdivided.

The next year, the Second Principal Meridian was laid out, at first a short distance north, then south about thirty miles to the Ohio River. In that season and during the next seven years surveys were extended in all directions until the ceded lands had been covered. The subdivisions immediately followed the Indian cessions, which were five in number.

Mansfield's work was necessarily confined to the southern part of the territory. The whole central part was Indian land until 1818 and the northern part still later. In 1819 surveys were immediately extended northward and the country opened to settlement. This is why the base line was placed so far to the

south. It was the Vincennes Tract that governed the location of both Principal Meridian and base line.

At the end of Mansfield's term of office in 1812, the Second Principal Meridian had been laid out about fifty miles north of the base line. That part of Indiana below or south of the townships numbered ten north had been covered with surveys and to some extent northwest of this in the vicinity of Terre Haute, also a narrow tract, twelve miles wide, on the east and immediately west of the Greenville Treaty line, extending half way up the western border to Fort Recovery, known as the Harrison Purchase, and ceded in 1809. This was all that could be done up to that date, and comprised about the south third of the territory.

The Indiana base line was extended west through Illinois to the Mississippi River, and the Third Principal Meridian south to the mouth of the Ohio, opening up the Illinois system of surveys. All the country south of the base line was subdivided in 1813 and 1814 and the lands put on the market. The Third Principal Meridian was not extended north of the base line until 1815.

There is nothing on record to show that Mansfield planned the Fourth Meridian, which was surveyed in 1816, but he probably did. E. D. Mansfield says in his "Personal Memoirs" that his father established three principal meridians in Ohio and Indiana while Surveyor-General, but as he had nothing to do with the First Meridian, this must mean the Second, Third and Fourth in Indiana and Illinois.

The rectangular system of surveying when first enacted into a law was not complete. It was a structure well enough so far as it had been built, but it had no supporting framework. What should have been supplied at first was created last, and this was Mansfield's achievement.

It is true there had been principal meridians and base lines in the Western Reserve, the Military Tract and the Fourth System of surveys before the Indiana work was commenced, but they were boundary lines, used by the surveyors for numbering ranges and townships. It had not occurred to any one connected with the earliest surveys to establish lines for that special purpose.

In the country beyond Ohio, Mansfield found a vast tract inclosed by the Ohio and Mississippi rivers and the Great Lakes that some day would be covered with townships. There must be a base line of some kind which surveys could be commenced from and referred to. He conceived the idea of two astronomical lines, a meridian and a parallel of latitude, independent of any

state boundaries that might be subsequently established, from which the townships could be laid off in four different quarters, and not necessarily to a great distance. He simply established a primary control where none previously existed. When surveys had been extended sufficiently far from one base and liability to errors incurred, another could be established for a new system of work. The four quadrants were different fields where surveys could be conducted independently of each other and errors in execution reduced to the least possible.

This conception was, in fact, the rectangular system of coōrdinates put to a practical application on the western prairies and very probably derived from Descartes geometrical invention of 1628. The base line and meridian are the two axes, and the range and township members, the ordinates. A point in any quadrant is definitely fixed.

This was Mansfield's part in the formation of the rectangular system, a base or framework for an extensive system of townships covering a large tract of country, which would insure uniformity and regularity in the execution of the work, a plan so obviously excellent that it has been continued over the whole public domain. It is the extensive use that was subsequently made of Mansfield's improvement that raises it to importance which it otherwise would not have had.

The rectangular system, like all other great inventions, was more of a process of evolution than a first-hand creation, for which no one man is responsible. Mansfield has always occupied the most prominent position in the history of the early surveys, and no one would wish to detract from his reputation. Without his interior meridians and base lines the system would have been forever cumbersome and difficult to execute. In fact, it could never have been extended over an extensive country as it had been conducted in Ohio. He was the first to plan and superintend a correct system of surveys which has been a prototype for all those that followed. On this alone, his reputation will always rest.

Nevertheless, it is evident when the actual historical facts are known that Mansfield's work in the development of the rectangular system has been overrated. Creditable as it was, it does not deserve the praise that has been attached to it when the work done before his time is considered. There is no great or original conception in the idea of the Indiana principal meridian with its base line. If General Putnam had been an educated and scientific surveyor, which he was not, he would have anticipated

Mansfield by establishing a base line for the fourth system of surveys instead of numbering townships from the Ohio River. Fortunately or unfortunately, Mansfield has received a considerable amount of advertising, for what very little there is on record about him and his work is entirely of that character, both misleading and incorrect.

Edward Tiffin's Record.

The rectangular system was not complete when Mansfield resigned his office in 1812 and it remained for Edward Tiffin, his successor, to supply the deficiency. So far during the progress of the surveys nothing had been done about the convergence of meridians. A tract of country was considered a plane surface, and the surveyors were attempting to divide it into squares with spherical lines as boundaries, an impossibility that had attracted attention at the earliest date. When the land ordinance was first reported in Congress in 1785, Timothy Pickering wrote at length to Rufus King, the Massachusetts delegate, and called his attention to this feature in the proposed method of surveying the government lands.

"The first paragraph orders the manner of dividing each new state into hundreds, but it seems to me it will be found impracticable. Each hundred is to be ten miles square, yet the lines making the eastern and western boundaries are to be true meridian lines, but meridian lines converge as you increase the latitude, and to such a degree that if you take any meridian, say at the thirty-ninth degree of latitude, and on that parallel set off ten geographical miles from such meridian, and then proceed northward to the forty-first degree of latitude, and then from the same meridian set off the like number of ten geographical miles, their extremity will be about eighteen hundred feet beyond the meridian, of the like extremity at the parallel of thirty-nine degrees. I am aware that mathematical accuracy in actual surveys may not be expected, but a difference of six hundred yards in ten miles would surely produce material errors." ("Life and Letters of Rufus King," Vol. 1.)

Congress paid no attention to this suggestion, and probably General Putnam never gave it a thought during the progress of the Ohio surveys. It would be doing Mansfield an injustice to say that he ignored it or intended to in his plan of improvements. But if he did propose or contemplate some method to obviate the difficulty, there is nothing on record to show it. That he did not establish a standard parallel from the Second Principal Meridian at thirty-six or forty-two or forty-eight miles north of the base line must have been because, in his opinion, the surveys had not

been extended far enough. However this may be, there is nothing to do but take the surveys themselves for a record and give Edward Tiffin the credit for providing a method to rectify this meridional convergence.

When the Indiana surveys were being extended northward after the Indian treaty of 1818 it would appear at first that he either ignored the convergence or was undecided when it had grown large enough to require correction. In 1819 the first standard parallel was run from the Second Principal Meridian ninety-six miles north of the base line, a distance too great, but the mistake was not repeated. The convergence of two range lines in this case would be about one eighth of a mile, or 640 ft., making a deficiency on the west side of townships altogether too large. He must have recognized this error, for in the same year he gave directions to all deputy surveyors about establishing a "new base or parallel to the equator" every twenty-four or thirty miles, lines which were known later as Standard Parallels or correction lines. (Niles Register, Vol. 16, p. 362.)

All of Illinois south of the base line was subdivided in 1813 and 1814, but a standard parallel was not considered necessary for the work, possibly because the tract of country was too small. After 1819, when William Rector was surveyor-general of Illinois, Missouri and Arkansas, one was surveyed on the west side of the Third Principal Meridian thirty-six miles north of the base line, another at fifty-four miles and a third one at thirty miles. On the east side they were placed at forty-eight, forty-two and thirty miles. At this date the Illinois system was far superior to any other work that had been done.

Edward Tiffin was surveyor-general ten years and made an excellent officer. Under his direction the Fifth Principal Meridian, the Michigan Meridian, was established, and perhaps the Fourth. He also adopted the west boundary of Ohio north of Fort Recovery as a continuation of the First Meridian and ran a base line for it on the forty-first parallel. He directed the surveys in central Indiana, in all the southern part of Illinois, to some extent in Arkansas and Missouri territories and all the northwestern part of Ohio, completing that state.

He made other valuable improvements towards systematizing surveys and methods and the sale of lands. He was the first to draw up an elaborate series of instructions for deputy surveyors in the conduct of their work, which governed all surveys for many years. These instructions were very complete and covered every detail of the work, prescribing one uniform method

which all were required to follow, and making a necessary interpretation to the land laws on the statute books at that time.

It would be quite correct to say that at the end of Edward Tiffin's service, the rectangular system of surveys was complete.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by February 1, 1909, for publication in a subsequent number of the JOURNAL.]

SOME OBSERVATIONS OF METHODS, COST AND RESULTS OF SEWAGE PURIFICATION ABROAD.

By H. W. Clark, Member of the Boston Society of Civil Engineers.

[Read before the Sanitary Section, October 7, 1908.]

To one familiar with sewage purification in America, there are a number of points in regard to sewage purification abroad that are impressed upon his mind more strongly by a short visit and inspection of English and other works than by much reading of engineering literature and Royal Commission or other reports.

In the first place, the number and proximity of sewage purification plants, especially in England, is forced upon one's attention at every hand; second, the variety of methods followed, and the variety often followed by one municipality, it being no unusual thing to find at one plant sewage farming, chemical precipitation, septic tanks, contact filters, trickling filters and secondary filters; third, the different methods of operating similar plants at different places; fourth, the curious lack of knowledge that often obtains at one borough in England in regard to methods and results at a neighboring borough in spite of associations of sewage works managers, etc.; fifth, the solidity and cost of works that are in a sense, even although the works of a large community, only experimental as yet; sixth, the fact that sludge disposal is still the chief problem in spite of all the work upon septic tanks and other methods of destruction; and, finally, the great part that chemical precipitation still plays at both old and new sewage plants, principally, however, as a preliminary treatment, although there are many huge precipitation plants without further methods of purification.

One has only to look over the curious mixture of works and methods to realize that in spite of vast expenditures, sewage purification in England is still in an experimental stage and that much money has been expended unwisely, in some cases, in endeavoring to meet the requirements of Rivers authorities and other official bodies without sufficient time for study and experiment, and in other cases simply from wrong construction. The report of the Royal Commission on Sewage Disposal just issued is, however, a comprehensive document, full of

valuable data and conclusions, and cannot fail to be of great aid in guiding the method of construction of plants yet to be built. This question of sewage disposal is a very serious one with our English friends, and they are taking it seriously and expending vast sums of money on every hand. In Germany, modern methods are not so much to the fore as yet, although good experimental work is being carried on and some elaborate screening plants are being erected. The Germans are watching English work, imitating it in some places, but are going slowly enough to avoid many costly mistakes.

During May, June and July of the present year I visited a large number of English and German plants and had an opportunity to talk with many of the prominent experts on this subject. To-night I propose to discuss the kind of sewage plants that are being built and operated in England and elsewhere abroad: how they are being built, why, and based upon what results; what some of them are costing, and, finally, to discuss the results.

Sewage Farming.

Sewage farming is still in successful practice in England at many places, and many of the modern works are part and parcel of the old sewage farms, built upon them and run in conjunction with them. Birmingham, for instance, where there is, as you know, one of the most notable displays of septic tanks and sprinkling filters in England, has besides this modern plant the old 3 000-acre sewage farm. This farm is being put out of use, however, and when the filters now under construction are finished, it will probably be entirely rented to farmers.

Of a number of farms that I visited, that at Wolverhampton, a city of 102 000 people, is representative, I believe, of good management under average conditions. The ordinary flow of sewage at Wolverhampton is 3 000 000 gallons daily and several times that during storms. All this sewage is cared for, however, which cannot be said of every English sewage farm. The sewage is first treated with lime and then passed through settling tanks to land. The farm is 600 acres in area, and of this area, 450 acres are used for sewage disposal. The sludge from chemical precipitation is pressed into cakes and burned or used to fill in lowlands over the farm. The sewage passes in shallow channels and the farm is drained with tile pipe 3 ft. 9 in. deep and with the lines of underdrains about 30 ft. apart. At times of excessive storm the storm-water flows into a storm

reservoir, eleven acres in area, with earth embankments 3 ft. high. Here it slowly filters away through the gravelly bottom. The effluent of this farm feeds a trout brook and, in fact, is perhaps the main source of this brook. It is, of course, good in quality and equal to that of the best Massachusetts sand filter plant. The total expenditure upon this sewage works and farm up to the end of March of the present year was $750 000, or about $7.50 per head of population. The cost of operation for the year ending March 31, 1908, less the profit from the farm, was $26 000. Including interest and sinking fund the yearly cost was slightly more than twice this, — about $56 000. The average rate of filtration on the farm is about 8 000 gal. per acre daily, the working cost $22 per million gallons and the cost per million gallons, including interest and sinking fund, $49. The cost of purification per million gallons at the eight farms reported upon by the Royal Commission in its recently issued report varies from a little less than $6 to about $77. I believe, however, that Wolverhampton is a typical farm, neither as large as that at Nottingham nor as small as some of the farms reported by this commission. In regard to sewage farming, the Commission states in its conclusions that where land can be bought for not over $500 per acre, land treatment is probably, other things being equal, the cheapest method of purification. With suitable land, it certainly gives the best results. From a cursory observation of English sewage farms I am led to believe that much of their ill repute is due to the use of land fairly well adapted to farming but poorly adapted to sewage purification.

Average Analysis of Wolverhampton Raw Sewage and Tank Effluent.*

(Parts per 100 000.)

	Ammoniacal Nitrogen.	Albuminoid Nitrogen.	Oxygen Absorbed in 4 Hours at 80° Fahr.	Combined Chlorine.
Raw sewage........	4.59	0.91	6.53	19.9
Tank effluent.......	4.79	0.45	4.64	19.0

Average Analysis of "Old" and "New" Land Effluents.*

(Parts per 100 000.)

	Ammoniacal Nitrogen.	Albuminoid Nitrogen	Nitric Nitrogen.	Oxygen Absorbed in 4 Hours at 80° Fahr.	Combined Chlorine.
Old land........	0.63	0.044	1.24	0.56	15.4
New land.......	0.68	0.042	1.11	0.52	15.0

* For year ended March, 1907.

Contact Filters.

As you well know, contact filters began to be talked about very earnestly about ten years ago and much was claimed for them. At the present time, while large contact filters are in operation at many places in England, notably at Manchester, and similar filters are being constructed on a large scale, notably at Sheffield, the general tendency is towards the construction of percolating or sprinkling filters. The forty-six acres of Manchester contact filters are of heavy concrete construction and the filtering material is coke or clinker. At the present time, owing to the better results known to be given by percolating filters, the Manchester authorities are experimenting upon changing the method of operation of these contact filters. That is to say, certain filters are being operated with unchecked outlets and with sewage flushed over the surface every fifteen minutes, the sewage rising in concrete chambers placed in the filters and spreading by means of surface channels. The new secondary filters under construction, in order that double filtration of the sewage may be possible, are being built to try to meet the requirements as to effluent of the Mersey and Irwell Joint Commission. They will be thirty acres in area. These filters are of heavy concrete construction, and while the first intention was to use coke or clinker as the filtering medium, it is probable that some at least will be of broken stone. The total cost of the Manchester works to date has been about $2 500 000 although a considerable portion of this has been for parts of the works not at present used, and the new beds, tanks and conduits will add $400 000. Thirty-five million gallons of sewage come to the Manchester plant daily with the average dry weather flow. No chemicals are used, but the sewage passes through large fat separators, so called, and septic tanks before going to the filters. At the present time all the contact filters are being cleaned; that is, all the clinker and coke in these filters is being removed, washed and replaced. This removal, washing and replacing costs about 15 cents per ton, and three hundred and fifty tons were being removed, cleaned and replaced daily at the time of my visit. As nearly as I can estimate from the Manchester reports, the working cost of this plant is 15 cents per person per year, or about $9 per million gallons of sewage filtered. One hundred and fifty men are employed. However, the effluent of this filter plant is pronounced unsatisfactory; in fact, "bad" by the Mersey and Irwell Joint Commission, and constant reminders are being sent to the Manchester authorities that its

FIG. 1. MANCHESTER CONTACT FILTERS.

FIG. 2. CONTACT FILTERS AT MANCHESTER CHANGED TO PERCOLATING FILTERS.

FIG. 3. BUILDING SECONDARY CONTACT FILTERS AT MANCHESTER.

FIG. 4. CONSTRUCTING CONTACT FILTERS AT SHEFFIELD.

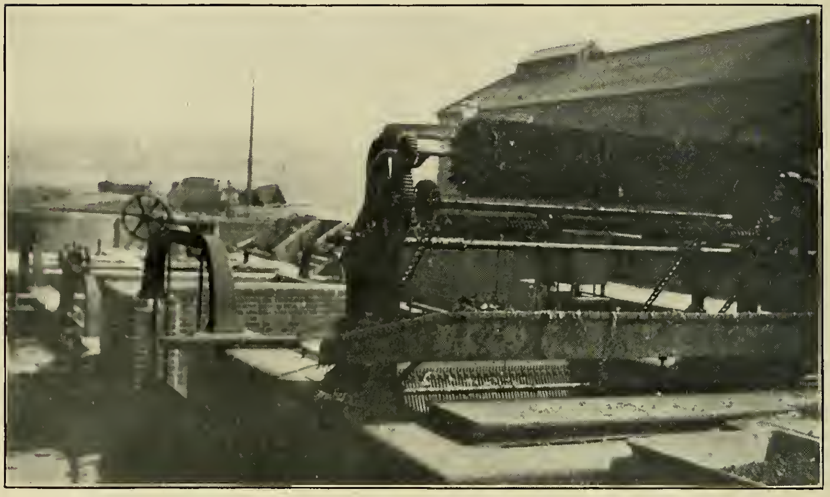


FIG. 5. A TYPICAL ENGLISH SCREENING PLANT.

FIG. 6. A TYPICAL GERMAN SCREENING PLANT.

quality must be improved. Owing to these reminders the secondary filters are now being constructed, but it is a serious question whether even with this addition to the plant the effluent will fulfill the requirements of the Rivers Commission. The effluent is often putrescible, according to Dr. Scudder, the chemist of the commission, and the purification not what it should be even though only a non-putrefactive effluent is the highest standard sought. No chemicals are used at Manchester, and Dr. Fowler, in talking with me in regard to the removal and cleaning of the material of all these filter beds, stated that in his opinion the retention of solid matter in them, even though this necessitated complete removal and washing of material every few years, was much cheaper than the use of chemicals to remove matters in suspension before filtration. This may be true, but the evidence of other contact filters in England is that much better effluents are obtained when chemical precipitation precedes filtration by such filters. I consider Dr. Fowler to have, perhaps, the greatest information in regard to sewage purification of any English expert, but I believe that the problem of making the Manchester filters do work satisfactory to the Mersey and Irwell Commission almost hopeless unless percolating methods can be adopted.

Notwithstanding the general disfavor in which contact filtration is held at the present time in England and the failure of the Manchester sewage works, according to the chemist of the Mersey and Irwell Joint Commission, such a community as Sheffield, having a population of 450 000 people and with an average daily flow of 15 0000 00 gal., is constructing contact filter beds. At Sheffield, since 1886, the main purification has been chemical treatment with lime and large settling tanks. In the new scheme, 16 settling tanks are being constructed, each with a capacity of 1 000 000 gal., and chemical treatment is to be omitted. The authorities at Sheffield state, however, that it is not intended to depend upon septic action in these tanks as a part of the scheme of purification. Thirty acres of contact beds in half-acre sections and sixteen acres of similar storm-water beds in acre sections are being constructed. All these contact beds are most solidly built with brick walls, concrete bottoms 6 in. thick and brick and concrete channels. The beds are to contain 4 ft. in depth of clinker over the underdrains, and the main underdrains are being built of concrete below the floor of the filter with tile coverings, and side drains 10 ft. apart entering these are laid on the concrete flooring.

The material of the bed is to be of graded clinker 3 to 6 in. in diameter at the bottom and becoming finer towards the top, the upper six inches to be constructed of clinker not more than $\frac{1}{4}$ or $\frac{3}{8}$ in. in diameter. The sewage is to pass to these contact beds through a channel built between each set and will enter the bed through a 2-ft. pipe to a chamber in the center of the bed where it will rise and overflow to a second circular chamber 15 ft. in diameter. From this it will pass over the surface of the beds in channels formed of the fine surface coke. The building of contact filters at Sheffield is a result of the operation for ten years, of large experimental contact filters treating 1 000 000 gal. of sewage daily. These filters produced an effluent equal to the requirements of the Local Government Board, and it is stated that the filtering material was never cleaned or renewed during their period of operation. The new filters are being built upon hard pan and clay, but notwithstanding this, the Local Government Board is insisting upon concrete bottoms 6 in. in thickness, causing a large expense that apparently is needless. The cost of the new plant complete is estimated at $1 500 000, or practically $60 000 per million gallons of daily capacity. The Royal Commission estimate the cost of a plant for contact filtration to vary from $42 000 to $134 000 per million gallons of daily flow, the cost varying with the preliminary treatment.

At Rochdale I saw five acres of contact filters that cost $6 000 per acre. These filters are simply excavations without concrete bottoms, and with earth instead of concrete dividing walls. The effluent was not particularly good on the day of my visit. At Blackburn there are four acres of contact filters, two primary and two secondary, and these filters receive about 1 200 000 gal. per day, or 300 000 gal. per acre. They are $4\frac{1}{2}$ ft. deep, of concrete construction and divided into many small areas; the filtering material is coke and clinker mixed, none of which is over $1\frac{1}{2}$ in. in diameter, and the sewage is treated with chemicals and passed through large settling tanks before filtration. Over the surface of the primary contact beds tile pipe is laid with close joints, and on the top of this tile pipe are fine slits about $\frac{1}{8}$ in. wide and 1 in. long, these slits being 4 or 5 in. apart. The sewage entering under the head given by its level in the sedimentation and septic tanks is projected upward from 3 to 5 ft. and sprays to a considerable extent, especially when the wind is blowing. From the primary beds the sewage passes to the secondary beds and is distributed by wide troughs laid closely over the surface of these beds. The troughs are about

6 in. deep and have $\frac{1}{2}$ in. holes near the top through which the sewage flows. On the day of my visit the effluent from the secondary filters was clear and odorless and contained about 0.06 of a part of albuminoid ammonia and fairly good nitrates. That is to say, at Blackburn, largely by use of chemicals and the removal of most of the suspended matter, and by double filtration through contact beds of fine material, a satisfactory effluent is obtained. These four acres of contact beds cost $100 000.

Sprinkling Filters.

I saw in England and Germany representative percolating or sprinkling filter plants. Such plants as those at Salford, Heywood, Horwich, Blackburn, Accrington, Chesterfield, Buxton, Hanley and Birmingham illustrate most, if not all, types of construction and operation, and produce a variety of results.

I shall talk briefly to-night about six or seven only; namely, the plants of Heywood, Blackburn, Chesterfield, Hanley, and Birmingham. These are typical plants of representative cities. The Heywood plant I was told by the Mersey and Irwell River authorities was giving one of the best effluents in the neighborhood of Manchester. Heywood is a city of 27 000 people, about eighteen miles from Manchester, and has an average daily flow of 1 100 000 gal. of sewage. The sewage is first screened, then treated with chemicals, passed through settling and septic tanks and then to sprinkling filters. A small portion of the sewage, however, passes to contact and sand filters that have been in use for quite a number of years. The chemical used is alumino-ferric, and the amount about 4 grains to the gallon. Mr. Bolton, manager of the works, stated, in distinction from the statement of Dr. Fowler, that the use of chemicals was in his opinion cheaper than removing, cleaning and washing filter material. The screens used are typical of those in use all over England, with automatic rake and brush cleaners moved by power. The power employed at many places about this plant is generated at a garbage disposal plant on a hill just above the sewage works. An automatic apparatus is in place to change the flow of sewage from one bed to another. It is a most complicated and ingenious affair, but I understand works fairly well. There are six or seven men employed all the time, however, within a stone's throw of the little house in which this apparatus is lodged, and possibly manipulation by hand

would be fully as sure and effective. Automatic apparatus is common in England at many of the sewage works, but in many places it is evident that it causes much trouble. The sprinkling filters at Heywood are 12 in number, 60 ft. in diameter, or about $\frac{1}{15}$ of an acre in area, and 8 ft. in depth. They have brick pigeon-hole walls, 15 in. thick at the bottom and 9 in. at the top, heavy concrete bases, and the sides are buttressed, owing to springing of these sides after they were built and filled with clinker. They are filled with pieces of clinker each with a diameter of 5 to 6 in., and each filter generally operates an hour and then has an hour of rest. The sewage is distributed by the revolving type of distributor, the so-called "simplex" distributor being in use here. The usual rate of filtration is 1 400 000 gal. per acre per day. The effluent of the filters passes through a settling basin holding about four hours' flow, then over baffles into the river Roche. On the day of my visit the final effluent was very handsome, well nitrified, and practically all the matters in suspension were being removed by the final settling tanks. The effluent made a clear streak in the river Roche into which it flowed; that is, it was of a much better appearance than the river water, although I was told by Mr. Bolton that the river had been improved very much of late years. Each filter cost, complete, with sprinkling apparatus, $2 900, or $34 800 for the set of 12 beds or $43 500 per acre of filter surface. Of course this is only a portion of the cost of the plant; the total cost for chemical precipitation plant, screens, settling tanks, etc., was $325 000. The working cost per million gallons of sewage treated is $10.50, practically the same as for chemical treatment alone at Worcester, Mass.

Blackburn is a city of 100 000 people and resembles somewhat in size and character the city of Lowell in this state. The average daily flow of sewage at Blackburn is 5 000 000 gal., although this doubles and triples at times of storm. A sewage farm has been in use for many years, consisting of 500 acres of land, largely clay land, let out to farmers. This farm is being abandoned and very elaborate and expensive new works are partly built and partly under construction. Sewage comes to the works and passes through screens cleaned with revolving rakes in the usual manner, these rakes being operated by a water-wheel set in the sewage channel behind the screen. About half of the sewage passes to large septic tanks and the other half is treated with 5 grains of alumino-ferric per gallon, then passes through a mixing channel to twelve large sedimen-

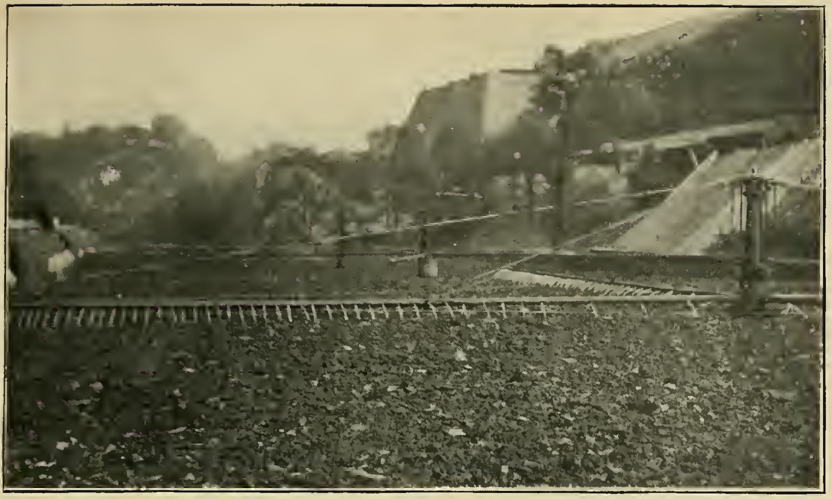


Fig. 7. Sprinkling Filter at Buxton.

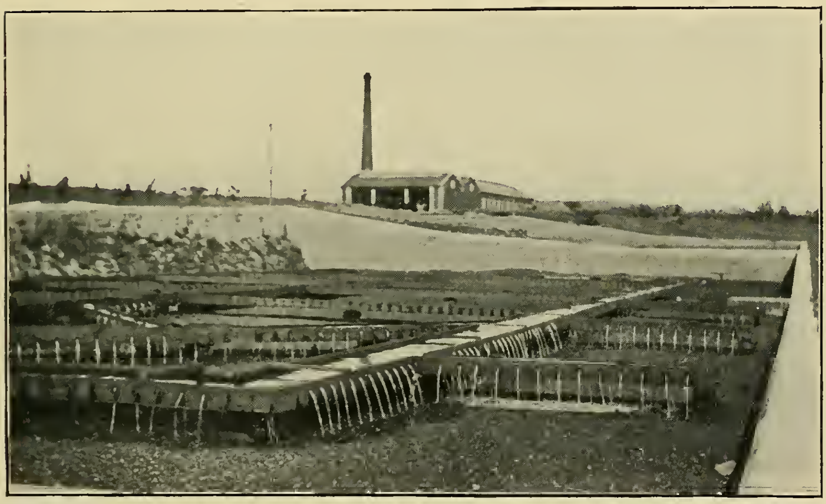


Fig. 8. Secondary Contact Filters at Blackburn.

Fig. 9. Sprinkling the Primary Contact Filters at Blackburn.

Fig. 10. Constructing Sprinkling Filters at Blackburn.

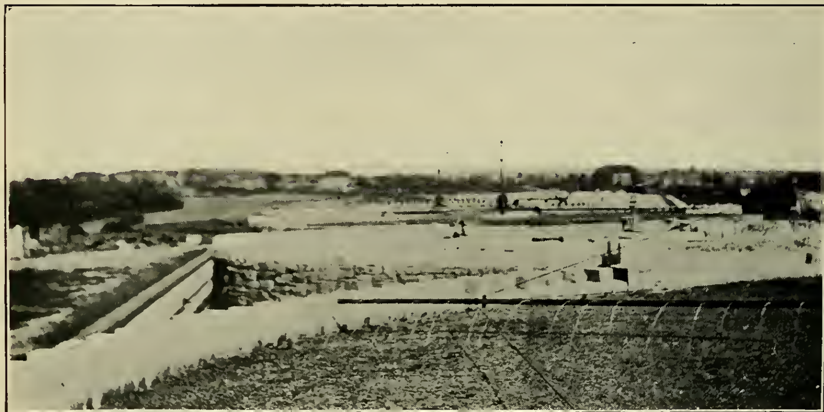


Fig. 11. A Few of the Blackburn Sprinkling Filters.

Fig. 12. Sprinkling Filter at Chesterfield.

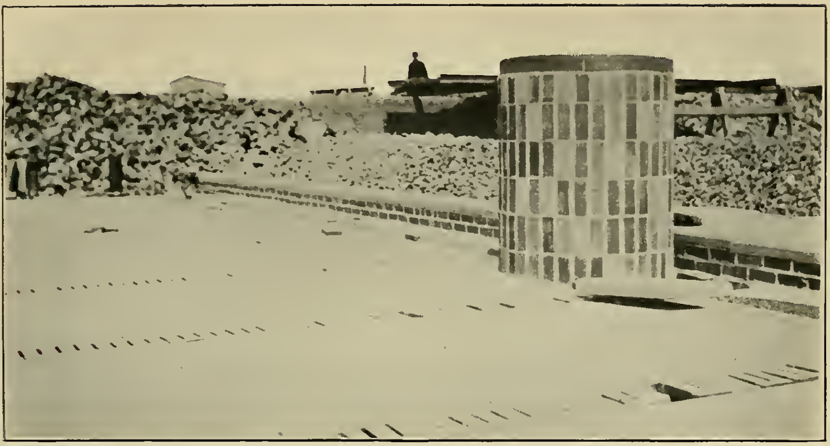


Fig. 13. Underdrains at Hanley.

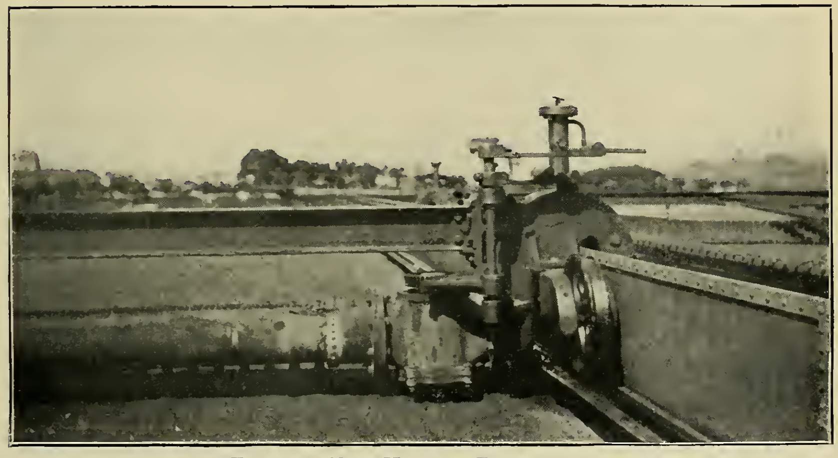


Fig. 14. The Hanley Distributor.

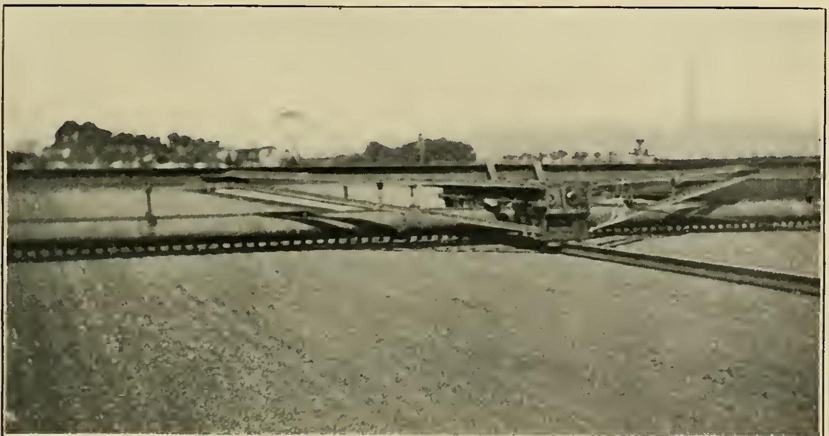


Fig. 15. The Hanley Distributor.

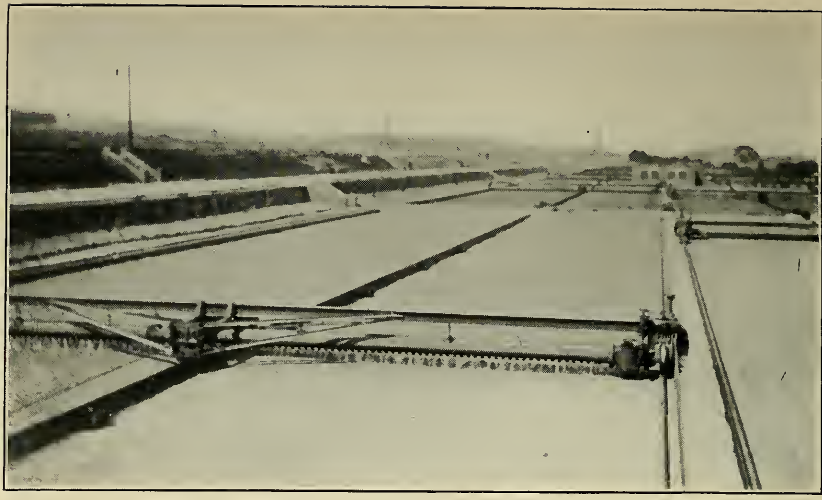


Fig. 16. Hanley Distributor and Filter Beds.

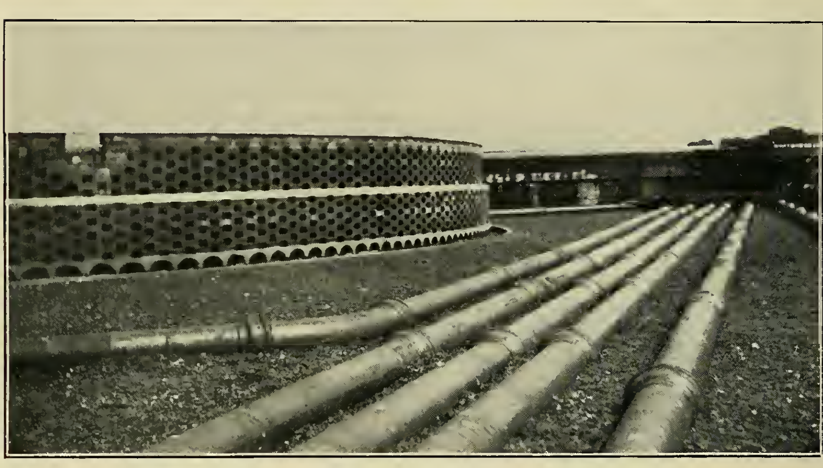


Fig. 17. Horwich.

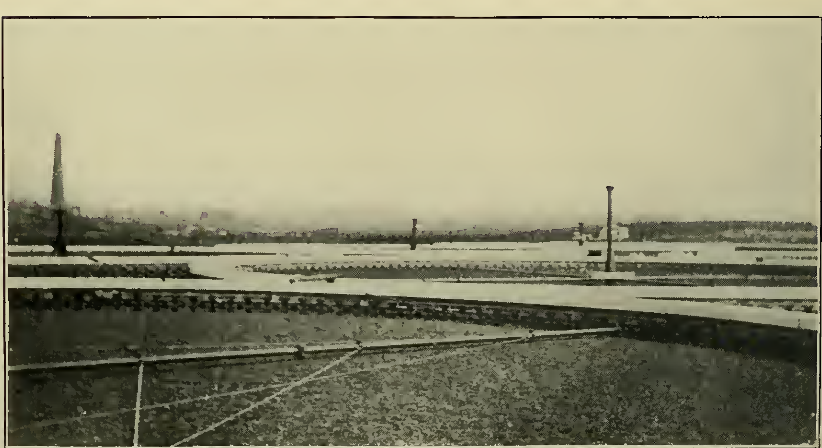


Fig. 18. Horwich.

Fig. 19. Building Storm Filters at Birmingham.

Fig. 20. Storm Filters at Birmingham.

Fig. 21. Cleaning Nozzles: Birmingham Sprinkling Filters.

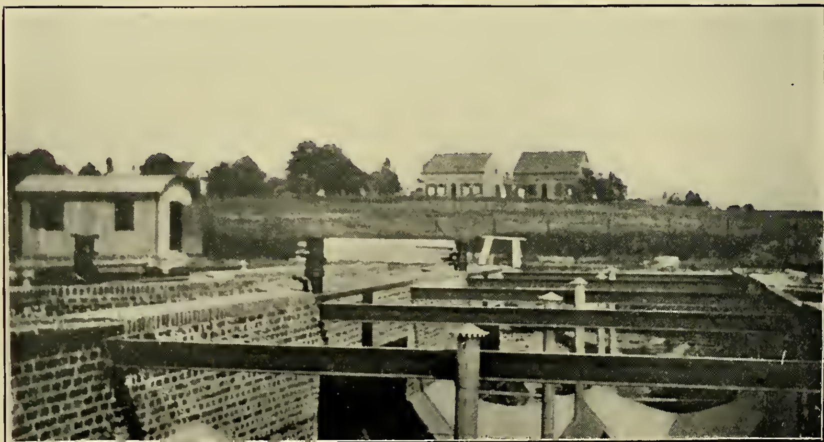


Fig. 22. Imhoff Septic Tank, Essen.

tation tanks, these tanks holding about 5 000 000 gal., or a day's flow in dry weather. The septic sewage is, however, treated with a small amount of chemicals before filtration. The alumino-ferric used is made at the plant from shale taken from a quarry on the farm, and costs about twenty-seven shillings per ton. From the sedimentation and septic tanks part of the sewage passes to contact and part to sprinkling filters. I have already spoken of the contact filters, and there are either finished or in course of construction 24 sprinkling filters, 80 ft. in diameter and 9 ft. deep. These filters are very heavily built with concrete bases and heavy stone sides. The stones in the sides do not fit particularly close but, nevertheless, present the appearance of a fairly smooth cut-stone wall. At the bottom of the filters, practically touching each other, are semicircular tile pipes 12 in. in diameter in 3-ft. lengths; that is to say, the entire bottom is covered by these underdrains. These filters are not entirely separate as at Heywood, but run together at one point, that is, touch each other, but heavily walled concrete channels run around each at the bottom passing under the filters at the junction of each pair. Along one side of each set is a straight, heavy, concrete main effluent channel. The filters are constructed of graded material. On the bottom are large pieces of destructor clinker. This layer is about 1 ft. in depth and above this layer the remainder of the filtering material is broken stone, coarse at the bottom, but growing rapidly finer towards the top until at the top the pieces are not more than one-half in., or less, in diameter. This stone seems to be rather soft and the top layer appeared to be disintegrating and the filters were pooling. The effluent of these filters passes over a weir into two Dortmund-shaped tanks, 28 ft. in depth; then from these tanks it passes into the Derwent River. At the time of my visit the Dortmund tanks were covered with a scum apparently putrefying and the effluent of the sprinkling filters as it passed into the river was poor, certainly not non-putrescible, but this was due not to the fault of the method of filtration but to the method of construction of the sprinkling filters. That is to say, the filters had undoubtedly too much fine material in the upper layers, and by close construction of the sides, together with the pooling at the filter surface, the air supply was shut off. While the plant was very imposing and handsome it was not making the returns in purification that it should for the expenditure that had been made. On all the trickling filters the sewage was being distributed by re-

volving distributors. This entire plant, including the original sewage farm, had cost $1 300 000. The modern part, about $500 000, divided as follows: settling tanks, mixing house, sludge-pressing house and machinery, $230 000; contact beds, $100 000; septic tanks, Dortmund tanks and sprinkler filters, $112 000. The sprinkler filters, 80 feet in diameter, cost $5 000 each, or about $42 000 per acre.

Chesterfield is a city slightly larger than Heywood; that is to say, it contains 35 000 people, and the normal flow of sewage is 1 000 000 gal. per day. The sewage area, in distinction from the plants at Heywood and Blackburn, showed a pleasing simplicity and cheapness, but was turning out an effluent better than that at Blackburn and fully equal to that at Heywood. Nominally, there are 17 circular filters. Really, however, the bed is all in one piece without elaborate retaining walls and without concrete bottom. That is to say, the filters all run together, but there are 17 rotary distributors, the corners where the arms of the distributors do not reach simply being left unfilled with clinker in most instances. The beds varied from 5 to 8 ft. in depth. The distributors were all made in Chesterfield and not patented, but were of the usual Barker mill type. The circular areas to which the arms of the distributors reached varied from 90 to 104 ft. in diameter. The cost of the beds was about $2 125 each, or practically $40 000 for the entire area, about $12 500 per acre, this including preparation of site, distributors, etc. No chemicals are used at Chesterfield, sewage being simply screened and then passed through settling tanks having a capacity of 700 000 gal. Formerly these tanks were used as septic tanks, but as they filled with sludge they are now cleaned out regularly every three or four weeks. The plant is on the site of the borough sewage farm, started in 1879, and the present filters have been in operation six years. They are in good condition and show no signs of clogging. The material in them, largely destructor clinker, varies from 6 in. to $\frac{3}{8}$ in. in diameter. On the day of my visit the effluent was clear, with very little suspended matter, and nitrification was good, judging from the analyses shown me by the manager. Six men are employed at the works and the total yearly cost of operation including pumping is about $3 000, giving a working cost of about $9 per million gallons treated.

The following were given me as representative analyses of the Chesterfield sewage, of the effluent of the tanks and of the effluent of the sprinkling filters.

(Parts per 100 000.)

	Free Ammonia.	Albuminoid Ammonia.	Chlorine.	Nitrates.
Sewage....................	1.88	1.36	9.80	....
Effluent of tanks..............	1.16	0.50	8.60	....
Effluent of sprinkling filters....	0.16	0.067	8.00	1.76

The sewage plant at Hanley is probably the handsomest and most striking of any that I saw during my visit to England, and, take it all in all, one of the most interesting. I believe it is practical also, in spite of what seems the almost unnecessarily costly equipment. Hanley is a city of 70 000 people, and has an average daily flow of sewage of 2 000 000 gal. and a wet weather flow at times of 9 000 000. The sewage at Hanley began to be purified about thirty years ago. About twenty-five years ago the purification was about as follows: Chemical precipitation, sedimentation and filtration through specially prepared sand filter beds, 12 in number, of about an acre each, with underdrains at the depth of 5 ft. and about 18 ft. apart. The rate of filtration of the chemically clarified sewage was about 100 000 gal. per acre daily. This was really an intermittent sand filtration scheme, preceded by chemical precipitation, and the character of the effluent was that which would be expected from such filters — entirely satisfactorily. A large volume of mine water was discharged into the sewers, together with wastes from pottery works, Hanley being a center of the pottery industry. The wastes from the mines were charged with salts of iron, the waste from the pottery works with clay, and these two bodies aided in clarification by chemical precipitation. It was not until about eleven years ago that this scheme began to be badly overworked. At that time — 1897 — a so-called purification syndicate agreed to purify all the sewage by a patent process, and their proposition was accepted by the borough council. The method of this syndicate was to sterilize the sewage and to aid precipitation by a solution of perchloride of iron in conjunction with the salts of iron and clay from the mining and pottery wastes. It is stated a carbolic solution in the form of vapor was forced into the sewage during its discharge down the carrier after chemical precipitation. It is also stated that although this thoroughly sterilized the effluent the very large amount of organic matter remaining in it, putrefied when mixed with the water in the river, sterilization being overcome by dilution. The method was abandoned and the present plan was adopted. The sewage passes through

the usual screens with automatic cleaners, then through detritus tanks with a capacity of 250 000 gal., and septic tanks with a capacity of 5 000 000 gal. There are to be $9\frac{1}{2}$ acres of sprinkling filters, 9 in acre beds and one $\frac{1}{2}$-acre bed. The acre beds, however, are practically divided by the sprinkling apparatus into four equal parts about 200 ft. long and 50 or 60 ft. wide. The construction of the beds is very handsome, brick walls and 6-in. concrete bottoms. Glazed tiles are prominent in many parts. The drains in the bottom consist of semicircular tile pipes set in concrete with the upper edges nearly flush with the concrete floors of the filters. Over these drains square brick-like tiles are placed close together, these tiles having three or four slit-like openings on top, also openings along the sides at the bottom. Over these underdrains is placed a layer of broken brick about fist-size, and above this layer 5 ft. in depth of broken saggers, the pieces being $\frac{3}{8}$ to $\frac{1}{2}$ in. in diameter. This is very handsome material, richly colored and, on the whole, the beds are the handsomest of any that I visited in England. The distributing device is as follows: On the side of each filter and section a track is laid and also a channel or trough into which sewage is delivered. Stretching over each section of the filter is a heavy iron distributor, a bridge-like structure operated by means of an endless wire rope coming from a power-house at the end of each filter, the power used being a $1\frac{1}{2}$ h. p. motor in each power-house, and the electric power is supplied by the electric plant owned by the borough. The endless rope turning a wheel causes the distributor to move slowly from one end of the filter to the other. When reaching the end, an automatic device in the power-house comes into play and the belt turning the wheel, around which passes the endless rope, is slipped upon another gear moving in the opposite direction. This reverses the direction in which the wheel turns and the distributor is moved across the bed in a reverse direction. The sewage is siphoned from the channels or troughs along each section into the pipe in the distributor. From this pipe it is delivered through many small openings in the bottom upon dash plates which sprinkle it on the surface. When reaching the end of the filter a projecting arm moving a lever shuts off the sewage and the distributor travels back to the other end of the bed without delivering sewage. That is to say, sewage is distributed only when the distributor is traveling in one direction, every alternate journey being an idle one. As it takes three minutes for the distributor to travel across the bed, each point of the

filter rests 6 minutes after receiving sewage before it is flooded again. The sewage applied to these filters was practically free from suspended matter and the effluent was very handsome on the day of my visit. It was as clear practically as the effluent of a good sand filter. The rate of filtration is said to average 750 000 gal. per acre daily. The filters are said to have cost $27 500 per acre, and the sprinkling apparatus $6 000 per acre. The entire cost of the as yet unfinished plant, including detritus and septic tanks, was estimated to be $375 000, and the estimated capacity is 9 000 000 gal. per day, or about $42 000 per million gallons daily capacity. The actual cost I was assured, however, will be in the neighborhood of $500 000, or $55 000 per million gallons. The cost of running the distributors is not counted, as the electric power is supplied by the borough plant, but it is evident that the Fiddian distributor could, under most conditions, be used in these rectangular beds. The filters were operating at a rate probably not greater than 600 000 gal. per acre daily at the time of my visit, the sewage applied was practically free from suspended matter and the effluent resembled a good sand filter effluent — clear, odorless, colorless and highly nitrified. In order to successfully operate trickling filters constructed of material as fine as that at Hanley without clogging, a very clear sewage must be applied. The Hanley sewage was of the required character, and it is probable that the mine drainage and pottery wastes still aid in clarification in the septic tanks.

The following analyses are given in a recent Hanley publication as representative of the sewage before and after treatment in the septic tank and the effluent of the rectangular filters.

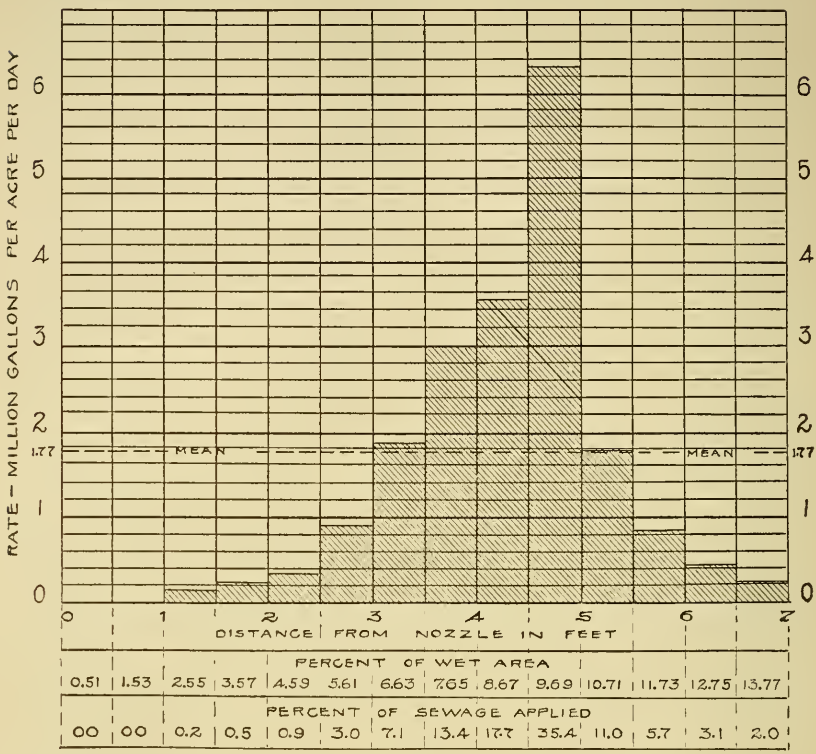
Analyses of Sewage and Effluent.

(Parts per 100 000.)

	Solids.			Ammonia.		Chlorine.	Nitric Nitrogen	Oxygen absorbed in 4 Hours at 80° Fahr.
	Total.	In Solution.	In Suspension	Free.	Albuminoid.			
Raw sewage..	188.3	125.4	62.9	2.109	0.765	8.9	0.00	3.854
Septic sewage	109.7	105.3	4.4	1.820	0.270	8.7	0.00	1.725
Effluent of filters	112.4	112.0	0.4	0.081	0.029	8.5	1.75	0.273

Birmingham at the present time passes its sewage through detritus tanks with a capacity of 5 000 000 gal. and septic tanks

RATES OF FILTRATION UPON DIFFERENT PORTIONS OF SURFACE COVERED BY A BIRMINGHAM SPRINKLER UNDER 6 FOOT HEAD WITH THE NOZZLE ON SURFACE OF FILTER



with a capacity of 7 000 000 gal. Practically all the sewage is cared for upon trickling filters, although some still goes to the 3 000-acre farm. Near the septic tanks are 4 acres of so-called storm beds in use all the time, however, and 30 acres of storm beds are being built. These are all sprinkler filters 6 ft. deep, filled with clinker, but with a few inches of broken stone on the surface. All beds have concrete bottoms. In the storm beds the tile underdrains are several feet apart, with large cobblestones between, while in the sewage beds proper, tile underdrains cover the entire bottom. At the area of sprinkler filters five miles below the septic tanks and storm filters, all the beds are of broken stone of the same grade practically throughout the entire depth, the pieces being from $\frac{3}{4}$ to 2 in. in diameter, and the sewage is applied — generally under a head of 6 ft. — by the well-known Birmingham sprinkler nozzles inserted in surface pipes. The beds are 1, 2 and 3 acres

in area, and all have heavy side walls. These beds cost $30 000 per acre. The septic sewage before filtration passes through large Dortmund tanks at this lower area, and after filtration through somewhat similar tanks. At the time of my visit the final effluent was much inferior in appearance to that at Heywood, Chesterfield, Hanley, Buxton and other places, although such analyses as I have seen show it to be generally high in nitrates and non-putrescible. The following analyses of Birmingham sewage and effluent are taken from the Royal Commission report.

ANALYSES OF SEWAGE AND EFFLUENT.

(Parts per 100 000.)

	Solids in Suspension.	Ammoniacal Nitrogen.	Albuminoid Nitrogen.	Nitrates.
Raw sewage........	48.4	3.67	0.98	....
Septic sewage.......	13.8	6.39	0.71	....
Final effluent.......	....	2.86	0.29	2.11

The rate of operation of the filters is practically 900 000 gal. per day. Twenty-three acres are in operation here and seven acres are being constructed. The cost of maintenance of the Birmingham complete works is about $40 per million gallons treated.

At Wilmersdorf, Germany, I took my last look at a sprinkling filter plant: 56 sprinkling filters, 60 ft. in diameter, constructed entirely of coke, the sides being simply large pieces of this material. The sewage first passes through septic tanks, then to these filters; settling basins follow and then sand filters. The sand filters at Wilmersdorf are called "Chorley Filters," as similar sand filters are in use at Chorley, England. A recent Chorley report states that intermittent sand filtration was "discovered" there a few years ago. The Wilmersdorf plant is eighteen miles from Berlin in a large sandy plain with very few houses in sight. The sewage, about 5 000 000 gal. daily, travels eighteen miles to the disposal area. A septic tank was being cleaned on the day of my visit and the sludge was so thick that sewage was being run in to liquefy it in order that it might be forced through the pipes leading to the sludge basins. Men were down in the basin stirring the sludge with poles. This plant is for a population of 60 000 now and is to be increased to care for 260 000. The final effluent was dark but odorless and was running into the Tetlow canal very close to well-patronized beer gardens. This plant has cost about $500 000 up to date.

Preliminary Treatment.

Every sewage plant that I visited had a more or less expensive system of preliminary treatment of the sewage, generally chemical precipitation with alumino-ferric or lime. At Heywood, Salford, Buxton, Rochdale, Blackburn, Chorley, York, Bradford, Leeds, Sheffield, Wolverhampton and other places, screens, chemicals, generally alumino-ferric, lime or iron salts, and ample settling tanks before filtration are employed. At Bradford and Leeds this is the entire treatment at present, except for a few small outlying sewage farms and trickling filters, and filtration is hardly being considered, although Bradford has purchased land for the erection of filters at some future time. Leeds, on the other hand, is building a large and improved precipitation plant. At other places, as at Manchester, Chesterfield, Accrington, Birmingham and Horwich, screens and settling or septic tanks are in use. At none of the places that I visited was any attention being paid to septic tank patents. At many of the places the sludge was pressed, at others lagooned until dry enough to handle and then carted away to farms, shipped in canal-boats to farms, dumped into lowlands, abandoned coal mines, or buried in land. At a few places it was being burned in destructors, and at Bradford preparations were being made to use it in the production of gas. At none of the places I visited did I find it being plowed in. At York, the sod and soil are stripped from a field and eight or nine thousand tons of sludge are buried yearly after pressing; then the sod and soil are replaced. There is at York at the present time a field of sludge 9 to 14 ft. deep and 9 acres in area, the accumulation of the past five years. Four men are continually employed at this sludge burying, and a handsome field of a somewhat higher grade is the result. At Birmingham, plowing in has been abandoned as thirty or forty acres were required for this purpose yearly and crops were poor. A large new area, many acres in extent, is now available, and to this the sludge from the septic tanks flows and is lagooned. It is a three-cornered area inclosed by railroad embankments. Sections are divided off by low earth embankments and gradually filled with the constant flow of black, liquid, but odorless sludge. Mr. Watson, the engineer of these works, states that he is not only disposing of sludge effectively and without offense in this manner, but also is making valuable land. In Germany, screening plants seem to have reached a high degree of efficiency, double and triple sets of screens being not uncom-

mon with the self-cleaning apparatus moved by power generated by water-wheels in the sewer.

Septic Tanks.

There is a general opinion abroad that septic tanks do not destroy even under the best conditions more than 25 per cent. of the organic matter entering them. At Hanley and Birmingham they say not more than 10 per cent. It is evident that at many so-called septic tank installations, the detritus tanks collect a large part of the organic matter. At Birmingham, for instance, the detritus tanks hold $\frac{5}{7}$ as much as the septic tanks, and, according to Mr. Black, the manager of these works, more than half the sludge is caught in these detritus tanks and removed from them. This sludge does not go to the septic tank sludge area. The greater the number of septic tanks that I inspect the more I am convinced that tanks for sludge only are by far the most practical. Such tanks may be small in comparison with the daily flow of sewage, and in them the organic matter has nearly an equal chance of change and destruction as in larger septic tanks and the sludge becomes concentrated in a shorter period of time. That is to say, a given weight of sludge contains a much less percentage of water, thus diminishing the volume of sludge greatly. At Essen, Germany, I was interested in the septic tank of the Imhoff Company. This Imhoff tank is simply a combination of large circular tanks with conical bottoms, the upper circular portions being connected by a straight channel through which the sewage flows. The matter in suspension in the sewage settles and passes into the septic tanks proper, where it remains for a matter of six weeks, while the main flow of sewage passes through quickly.

Odors of Septic Sludge.

I believe that it is pretty clear at the present time, judging from experience at home and abroad, that whether the sludge from septic tanks is offensive or not depends entirely upon the character of sewage entering these tanks, together with method of operation. Speaking broadly, the sludge of domestic sewage may, unless exceedingly old and well digested, be very offensive. It occasionally may not be, however, for reasons that cannot be explained. Certain wastes from manufactural industries may lessen the odors developed in septic tanks, and septic sludge and other wastes may increase them. I believe the entire lack of odor of the sludge from the Birmingham septic tanks to be due

largely to the iron and copper salts coming into the sewage from the industries of Birmingham. When this sludge is spread on the ground it appears to be poisonous to vegetation. Nothing, not even weeds, will grow in it unless it is mixed with other soil. At other places where brewery or wool wastes enter the sewage, the septic sludge may be, generally speaking, quite offensive. I can say from my own observations abroad, I believe that well digested septic sludge has generally much less odor than sludge from detritus and chemical precipitation tanks, and that the odor from precipitation and settling tanks is fully as great as that from most septic tanks.

Automatic Apparatus.

Nearly all trickling filters in England are operated intermittently. That is to say, the sewage is applied for an hour or more; then an equal period of rest ensues. There are, of course, filters, such as those at Hanley, where a more frequent period of rest is given, and at other places a longer period of operation. In one or two places, while the average rate of filtration was stated to be 1 000 000 gal. per acre daily, the filters were really operated at a rate of 2 000 000 gal. for 12 hours, then a second set operated for the remaining 12 hours of the day. The changing of the flow of sewage from one revolving sprinkler to another is generally attended to by hand, but in many places there are automatic devices in use. These devices were out of order at a number of places at the time of my visit. At most beds there was an ample supply of men working in the vicinity of these devices most of the day, and probably attention by hand would have been, to say the least, equally as efficient. At nearly all trickling filter plants in England some form of automatic distributor is in use, generally the Barker wheel type, the Fiddian, or modifications of these two, Birmingham and Salford being the only two large places at which I found sprinkling nozzles in use. When I started I was strongly inclined to believe that the use of nozzles was the common-sense method. I have become convinced, however, that under English conditions distributors of the Fiddian, Simplex or Hanley type are by far the best. It is evident that filters operated with this type produce better effluents, other things being equal, per unit of filter surface, and every square inch of filter can be used. By sprinkling nozzles operating under a constant head, as at Birmingham and Salford, as can be seen from observation of these areas, and as has been shown by experiments at Lawrence and elsewhere, only

about fifty or sixty per cent. of the filter is really used. That is to say, if 2 000 000 gal. of sewage are applied daily to an acre bed by means of nozzles, a considerable area will operate at a rate of five or six more million gallons per acre daily, while a portion will operate at a rate of half a million gallons or less. There is little or no spreading of the sewage as it passes through filters of clinker, coke or broken stone. In other words, if the sewage was as perfectly distributed over the Birmingham filters as over the Hanley, Heywood and other filters, the area of these filters might perhaps be reduced 50 per cent., the cost of construction be not much more than half as great, and the same purification result be achieved. Even in this country, I believe, perfect distribution, even if the form of distributor necessitates covered filters for good winter work, may in the end be the practical method of construction and operation. Sprinkling nozzles operating under a variable head improve distribution, but it is evident that nozzles call for constant attention. The men tramping over the Birmingham filters, one to every one and one-half acres, keeping the nozzles clear, have no sinecure. They are about the wettest objects at the plant. In cold American winter weather it would be a job requiring much fortitude. Distributing orifices can be much larger when the application is intermittent than when it is continuous, thus insuring less frequent clogging, and this is certainly one of the advantages of the intermittent operation of sprinkling filters. The Fiddian distributor I judge might be almost free from clogging, the sewage rising and emptying from the hod-shaped holders into the divisions of the wheel, the weight of the sewage turning the wheel and causing the distributor to roll around circular beds or forward and back on rectangular beds. All of these revolving Barker mill sprinklers or Fiddian distributors can work under a very small head. At one place I found revolving sprinklers working under a head of 4 in. Take it all in all, intermittent-continuous is the best designation of these filters. They are all percolating filters, but so is a sand filter; some have sewage sprinkled upon their surface, but so do some contact filters.

The Material in Contact and Sprinkling Filters.

In regard to contact filtration, I believe that all extended investigation proves that good work and long life of the filter depend on effective preliminary treatment of the sewage, more effective than the present Manchester treatment. I consider Dr. Fowler the foremost English authority on sewage purification,

but I very much doubt his ever accomplishing as satisfactory results with the present Manchester plant as would be possible if chemicals were used. Certainly the plant can never give results equal to the best plants at which the trickling filter is the main feature of the purification scheme.

There has been much said of late years of Dibdin's slate contact filters. The Royal Commission, in its latest report, however, states that from their own observations the results of these contact filters resemble the results of septic tanks rather than filtration results. In this connection I wish to call attention to the fact that a filter of roofing slate with regular ½ in. spaces between the slates was operated at Lawrence nearly eight years ago, and in the report of 1901 it was stated that the action in this filter was anaërobic rather than aërobic.

The filtering materials used most largely in contact and trickling filters are coke, clinker and broken stone, although burnt ballast I found being used in one or two places. There is no doubt that in contact filters coke and clinker give better results than broken stone, and the finer the material the better the purification of the applied sewage. If operating contact filters and removing material every few years to wash out the matters retained in them from the applied sewage is cheaper and more efficient than chemical precipitation, as Dr. Fowler states, there seems to be a wide opening for the use of contact filters as a preliminary treatment of sewage after sedimentation at purification plants. In trickling filters all grades of material are used. I found filters operating with pieces of clinker half a foot in diameter and the entire filter made up of this material, and at other places, filters with material not over ¼ or ½ in. in diameter throughout the entire depth, and at other places graded material. The best results were universally given, I believe, where the material was practically of the same grade throughout the greater depth of the filter with coarse material over and around the underdrains. Other things being equal, the finer and the rougher the material the better the effluent. At places where materials were mixed to any great extent, different grades of broken stone or different grades of coke, more or less trouble from clogging was occurring or had occurred. That is to say, just as we have found at Lawrence, we can run a good trickling filter with coarse stone, most of the pieces 2 in. in diameter; or a good trickling filter with fine stone, most of the pieces ¾ or 1 in. in diameter, but if the two grades are mixed, the open space is more completely filled and clogging may ensue. On the whole it

seems reasonable to assume that material of the grade used at Birmingham, for instance, is more practical, and under good conditions would give better results, than the grade used at Heywood, this depending, however, to a considerable extent on the degree of efficiency of preliminary treatment given the sewage. The Hanley material, except when receiving a sewage as beautifully clarified as that at Hanley, would prove altogether too fine.

Use of Chemicals.

The reason that chemical precipitation is employed so largely where modern filters are in use in England is that by such chemicals and sufficient sedimentation a liquor can be produced containing only about one third as much suspended matter as the same sewage after passing through ordinary septic or settling tanks. To be sure the sludge produced is almost three times that remaining after successful septic tank treatment, but a clear liquid is of the utmost importance in obtaining good and economical results from many English contact and sprinkling filters. The Royal Commission estimate that the sludge from chemical treatment of a unit volume of sewage will require nearly three times as much land per year for sludge burial as the sludge resulting from the same unit volume of sewage submitted to septic tank treatment, and that the cost for labor in this respect will be practically twice as great for the chemical as for the septic tank treatment. The cost per million gallons of chemical precipitation treatment, including loan charges, they estimate to be about $17, and of septic tank treatment, $8.50 per million gallons; that is, for these preliminary treatments only, omitting further purification. They estimate, however, that the rate of operation of trickling and other filters may be twice as great when receiving a sewage treated chemically as when operating with the same sewage treated in septic tanks. This means, of course, a reduction in filter area when the chemically clarified sewage is applied and nearly equalizes the cost. Including filtration loan, etc., the cost per million gallons is believed by the Royal Commission to be about $25 for chemically clarified sewage and $22 for sewage from septic treatment, this with open septic tanks. These costs are calculated from the results of various plants under observation by the Royal Commission for a number of years and assume practically perfect conditions. I have no hesitation in stating, however, that actually the majority of plants in England to-day would figure out a much greater cost

per million gallons than this. In the majority of cases the effluent produced at this cost is, perhaps, stable; that is, will not undergo secondary decomposition but generally contains, as is necessary and economical, practically as much suspended matter as in the liquid applied to the filters. Generally such effluents should be treated further by sedimentation and straining or filtering, if a clean as well as a non-putrescible effluent is desired.

Cost of Precipitants per Million Gallons Treated.

Alumino-ferric, a crude sulphate of alumina, is the precipitant most in favor at the present time in England, although, of course, lime and other precipitants are also used. At a number of plants that I visited, such as Chorley, Blackburn, etc., this precipitant was not bought but made at the plant. At other places, such as Buxton, lime is obtained very cheap owing to the plant being in the neighborhood of lime works, one almost overhanging the plant, as shown in the picture; and chemical precipitation was further cheapened at Buxton by the use of a constant stream of water piped from an abandoned colliery containing iron salts in solution, this small stream running constantly into the sewage just below the point at which lime was added. Owing to these facts the great variation in cost of chemicals may be observed. At Heywood the cost is \$6.50 per million gallons; at Rochdale, \$7.00 per million gallons, but at Chorley, Buxton and Blackburn, \$3.10, \$1.12 and \$2.60 per million gallons, respectively.

Strength of Sewage, Etc.

The average English sewage is not much, if any, stronger than that used at the Lawrence Experiment Station. For the last fourteen years the results of hundreds of analyses show the experiment station sewage to average about as follows:

(Parts per 100 000.)

Free Ammonia.	Albuminoid Ammonia.	Chlorine.
4.25	0.75	9.25

Comparison of the results of many analyses of rather strong English sewage given in following tables follows, these analyses being taken from the Royal Commission report. In many English cities and towns the small volume of sewage per inhabitant is partly due to the not uncommon continuance of the old pail system in sections of these towns and cities.

The effluents of English filter plants do not differ from effluents produced by various filters at the Lawrence Experiment

Station. The effluents of properly constructed and operated contact and sprinkling filters at Lawrence are of the same quality as those of the best English contact and trickling filters, and poor effluents are the rule in England as well as at the station when the filters are not constructed according to the best designs. Data in regard to rates, clogging, etc., are very similar.

Tables appended to this article are either taken directly from the fifth report of the Royal Commission on Sewage Disposal or made up from figures given in that report. Table No. 1 illustrates the character of sewage of different English cities, the strength of this sewage, the results of septic tank treatment and the ordinary disposition of sludge. Table No. 2 reports the results of chemical precipitation of the sewage of certain English cities. Table No. 3 shows the results of various percolating filters, the method of distribution, analysis of final effluent, etc. Table No. 4 is copied directly from the report of the Commission and shows their estimate of the cost per million gallons of treating upon sewage farms the "dry weather flow" of the sewage of these cities and towns. Table No. 5, taken also directly from the report, gives their estimate of cost per million gallons of various preliminary treatments of sewage followed either by contact or percolating filter treatment.

TABLE No. 1.

TREATMENT OF SEWAGE IN SEPTIC TANKS.

Place.	Population.	System of Sewage.	Dry Weather Flow of Sewage. (Million Gallons.)	Nature of Sewage.	Analysis of Sewage. (Parts per 100 000.)			Rate of Flow through Tanks (expressed in time taken to fill tank in dry weather).	Analysis of Septic Tank Liquor. (Parts per 100 000.)			Tanks Cleaned.	Method of Disposing of Sludge.
					Ammoniacal Nitrogen.	Albuminoid Nitrogen.	Suspended Solids.		Ammoniacal Nitrogen.	Albuminoid Nitrogen.	Suspended Solids.		
Accrington...	46 300	Combined.	1.18	Strong domestic	5.18	0.68	43.3	42 hr.	5.03	0.34	19.4	Every 4 to 6 mo.	Lagooned and sold when dried.
Birmingham .	865 701	Combined and partially separate.	22.0	Trade sewage.	3.67	0.98	48.4	10–12 hr.	6.39	0.71	13.8	Septic tanks periodically.*	Buried in adjacent ground.
Leeds	450 142	Combined.	16.0	Trade sewage.	2.60	0.80	61.4	24 hr.	1.73	0.47	21.7	End of 2 yr.	Lagooned.
Manchester ..	575 000	Combined.	25.3	Trade sewage.	2.27	0.51	35.0	15 hr.	2.74	0.37	10.8	.....	Sent to sea.
Rochdale	52 000	Combined.	1.31	Domestic, with wool washings.	4.16	1.29	36.7	30 hr.	3.74	0.67	5.3	Every 6 mo.	Pressed and sold to farmers.
Sheffield.....	400 000	Combined.	14.5	Trade sewage.	2.61	0.76	50.2	24 hr.	1.96	0.37	..	At long intervals.	Lagooned.
York........	80 000	Combined and partially separate.	4.25	Domestic, with trades waste.	2.58	0.82	21.2	26 hr.	2.86	0.49	5.3	After 21 mo.	Lagooned.

* Roughing tanks once a week.

TABLE No. 2.

CHEMICAL PRECIPITATION FOLLOWED BY SETTLEMENT.

Place.	Nature of Sewage.	Analysis of Sewage. (Parts per 100 000.)		Precipitant used and Quantity added in Grains per Gal.	Analysis of Precipitation Liquor. (Parts per 100 000.)		Method of Disposing of Sludge.
		Ammoniacal Nitrogen.	Albuminoid Nitrogen.		Ammoniacal Nitrogen.	Albuminoid Nitrogen.	
Chorley ..	Domestic.	4.20	1.01	Alumino-ferric, 9.0 grains on average flow.	3.82	0.55	Pressed and sold to farmers.
Heywood	Domestic, with trade waste.	3.37	0.83	Alumino-ferric, 8.0 grains on average flow.	1.99	0.42	Pressed and taken by farmers.
Leeds....	Trade sewage.	1.95	0.68	Lime, 3 grains on average flow.	1.84	0.32	Lagooned.
Rochdale	Domestic, with wool-scouring liquor.	4.16	1.29	Alumino-ferric, 7.3 grains; vitriol, 4.7 grains, on average flow.	4.20	0.66	Pressed and taken by farmers.
Sheffield .	Trade sewage.	2.61	0.76	Lime.	1.09	0.15	Lagooned.
York	Domestic, with trade waste.	2.58	0.82	Alumino-ferric, 5.7 grains; lime, 4.3 grains, on average flow.	2.63	0.54	Pressed and buried under thick layer of soil.

TABLE No. 3.

PERCOLATING FILTERS.

Place.	Material used in Filters.	Depth of Material.	Distribution.	How Liquid is Delivered to Filter.	Analysis of Final Effluent (Unsettled). Ammoniacal Nitrogen, Hourly.	Albuminoid Nitrogen, Hourly.	Nitrates, Hourly.	Condition of Filters.
CRUDE SEWAGE: Leeds.	Clinker.	10 ft.	Tipping troughs.	Continuously.	...	...	...	Clogged after 1 month's work.
SETTLED SEWAGE: Leeds.	Coke.	9 ft. 6 in.	Sprinkler.	Continuously.	...	...	...	Unchanged after 1 year.
SEPTIC TANK LIQUOR: Accrington.	Coke or clinker.	9 ft. 3 in. to 7 ft.	Sprinklers.	Continuously.	1.07	0.27	2.24	Good after 4 to 8 years.
Birmingham.	Granite, quartzite, slag, etc.	6 ft.	Nozzles, etc.	Continuously.	2.86	0.29	2.11	....
Rochdale.	Coke.	9 ft.	Sprinkler.	Continuously.	...	...	...	Good after 7 years.
York.	Clinker, coke, slag, or broken brick.	6 ft. 6 in. by 7 ft. 8. in.	Sprinkler.	Continuously.	0.10	0.07	2.25	Good after 4 and 6 years.
PRECIPITATION LIQUOR: Chorley.	Sand, polarite, and gravel.	3 ft.	By fine material.	Intermittently.	1.07	0.09	2.35	Good after 12 years

TABLE No. 4.

FARMS WHICH WERE UNDER CONTINUOUS OBSERVATION BY OFFICERS OF THE COMMISSION FOR OVER TWO YEARS.

Place.	Population Draining to Farm.	Dry Weather Flow of Sewage in Gal. per 24 Hr.	Net Cost of Treating the Sewage per Million Gal. (including loan charges), based on the Dry Weather Flow.	Net Annual Cost of Treatment per Head of Population Draining to Farm, including Loan Charges.
Leicester	197 000	7 250 000	$28.15	$0.37
Croyden (Beddington)	100 000	4 000 000	26.85	0.38
Cambridge	50 000	2 250 000	11.35	0.18
Aldershot Camp	20 000	1 000 000	9.50	0.16
Rugby (high level)	6 000	300 000	7.40	0.12
Altrincham	18 000	800 000	5.80	0.08

TABLE No. 5.

COST OF PURIFICATION PER MILLION GALLONS (DRY WEATHER FLOW).

Preliminary Process.	Contact Beds.			Percolating Filters.		
	Total Cost of Preliminary Treatment.	Total Cost of Filtration Process.	Total Cost of Complete Treatment.	Total Cost of Preliminary Treatment.	Total Cost of Filtration Process.	Total Cost of Complete Treatment.
Quiescent settlement, with chemicals	$17.20	$10.95	$28.20	$17.20	$7.85	$25.00
Continuous flow settlement with chemicals	15.50	16.15	31.70	15.50	9.00	24.60
Quiescent flow settlement without chemicals	9.90	22.90	32.75	9.90	10.45	20.40
Continuous flow settlement without chemicals	7.75	27.75	35.50	7.70	10.23	20.90
Septic tanks	8.60	27.75	36.45	8.60	13.15	21.75

Cost per million gallons of land treatment on good land with cropping, $15.25.

DISCUSSION.

PROF. LEONARD P. KINNICUTT. — I consider myself as most fortunate in being able to be present this evening, and I wish first of all to congratulate Mr. Clark on his presentation of the subject. He has certainly given a very clear description of the plants visited by him during the past summer, and has shown us a remarkable series of slides. These plants are the most representative of modern sewage practice, and emphasize what is being done in Europe, and what may be gained by a careful study of the methods there employed. Europe is certainly greatly indebted to the work done by the Massachusetts State Board of Health, and we on the other hand should not be loath to acknowledge our indebtedness to the workers in England and on the Continent. As we all know, the contact bed and the bacterial percolating filter originated and were first brought into practical use in England, and, as Mr. Clark has shown, to study these methods in their fullest development, we still have to cross the ocean. The method of distribution of the sewage, especially on percolating beds, is one of very great importance, and I was particularly interested in what Mr. Clark had to say on this subject. I certainly agree with him that sprinklers give a very much better and more even distribution of clarified sewage than any of the nozzles now in use.

Sprinklers, however, as Mr. Clark says, could not be used in winter in New England with uncovered beds; but I am not sure that I quite agree with his tentative proposition of the possible advantage of covered filters with sprinklers over uncovered beds with nozzle distributors. It is, however, a point deserving very careful study.

In his description of the various plants, one of the most striking points is the carefulness and thoroughness of the construction of English plants, and the amount of money that is expended in what we are apt to consider non-essentials. Yet I think something can be said in favor of the thoroughness of English construction which gives even to a sewage plant a finish which attracts attention.

Of all the plants visited by Mr. Clark, the two which interest me the most, and which I visit and study every time I am in England, are the plants at Birmingham and Manchester, the best representatives, in my opinion, of the two methods of bacterial treatment, namely, percolating filters and contact beds. And I think from what Mr. Clark has said that he agrees with

me that the present trend of opinion in England is in favor of the percolating filter method of treatment, though much can be said in support of Dr. Fowler's statement regarding the cost of treatment by these two methods.

My visit to England this last summer was made to study the question as to the best method for clarifying sewage and for the disposal of the suspended matter. It seems to me that we do now know how clarified sewage can be treated so as to obtain non-putrescible effluents, but that much remains to be learned regarding the removal and subsequent disposal of the suspended matter.

In my study of this subject I visited and studied the hydrolytic tanks at Hampton, the Dibdin slate beds at Devizes, the large sludge basin at Birmingham and the experimental septic tanks of Dr. Dunbar's at Hamburg. The hydrolytic tanks at Hampton were constructed under the supervision of Dr. W. Owen Travis, the chief advocate of what is now known as the Hampton Doctrine. The belief of Dr. Travis and of his co-workers, among whom Mr. J. H. Johnson deserves special mention on account of his brilliant experimental work, is that the purification of sewage is not essentially a bacterial action, but is a physical process rendering the so-called soluble organic matter in sewage insoluble, namely, changing soluble colloids into insoluble colloids; and that bacterial action in sewage treatment is practically limited to the decomposition of the solid organic matter deposited in tanks, or deposited and absorbed by bacterial beds.

The results accomplished at Hampton and in the new hydrolytic tanks at Norwich, England, are certainly of such a character that they cannot fail to attract attention. Personally I believe that Dr. Travis's views will have a decided influence on future sewage treatment.

Dr. Dibdin's slate beds at Devizes, at High Wycombe and at Trowbridge are the visible results of Dr. Dibdin's belief that in the purification of sewage anaërobic action is unnecessary and that septic tanks render the treatment of sewage more difficult and offensive. There is no question that excellent results can be obtained from slate beds as a preliminary treatment, as is shown by the report of Dr. Fowler on the beds at Devizes; and from my own personal observations I was convinced that the sludge obtained by this process was of an entirely different character from the sludge of the septic tank, resembling very closely the sediment washed out from percolating filters.

The sludge basin at Birmingham is perhaps the most interesting and astonishing sight in connection with sewage treatment that I saw during the past summer All of the sludge from the second series of septic tanks at Birmingham, which is the largest installation of septic tanks in the world, is pumped to a large triangular area, two acres in extent, surrounded by earthern embankments, two of which are 20 ft. high, the other 10 ft. high. Into this area is pumped daily about 800 tons of sludge, the greater part of which comes from the second series of septic tanks, the sludge of which is removed on the average once a month, but a portion is practically fresh sludge from the first series of septic tanks. In this area, which is now covered to the depth of about 8 ft. with sludge, rapid decomposition of the solid organic matter is taking place, as is shown from the amount of gas being continually evolved; yet with all this decomposition no odor is perceptible when standing on the banks enclosing the area. Why this is so it is difficult to explain; possibly it is the character of Birmingham sewage containing, as it does, a larger amount of copper sulphate than any sewage which I have studied. Mr. Watson, however, has another theory, which I cannot, at this time, attempt to explain, though, like all Mr. Watson's ideas, it is deserving of the most careful attention.

Dr. Dunbar is well known to you all from his experiments, not only on sewage treatment, but from his brilliant work in various branches of sanitation. His experiments with his experimental septic tank receiving all the sewage from Hamburg's Isolation Hospitals has resulted in producing some of the best scientific work on sewage that has ever been published. He believes in anaërobic-action as a preliminary treatment of sewage, and his experiments have shown the remarkable effect of such action on large masses of animal matter, as the bodies of dead animals, and the difference in the action when fresh sewage is not allowed to enter the tank.

I should like to say something, also, regarding the opinions of many English sewage engineers as to the causes of the failures of the septic tank as commonly used as a method of preparing sewage for contact beds and percolating beds, and why Leeds has abandoned septic tanks in favor of chemical precipitation, but this, like the other subjects to which I have referred, requires too much time to be entered upon this evening, and, feeling that I have already taxed your patience, I will finish as I began, by congratulating Mr. Clark on having made this

meeting one of the very interesting meetings of the Sanitary Section.

Prof. C.-E. A. Winslow. — I was greatly interested in what was said to-night about the operation of trickling filters and about the Essen septic tank and the other points brought out. It seems to me that an enormous deal is being gained in the recognition within the last few years of the fact that we have three practically distinct problems to deal with — the removal of solid matter, the oxidation of organic matter (or the rendering stable of organic matter, I should say), and the removal of bacteria. Sometimes all of these are necessary, and sometimes only one or two of them, but the means to be adopted are practically distinct. We have various effective means for rendering stable organic matter, of which, I think it seems clear, the trickling filter, is on the whole, the most promising. You can't get away from that side of the problem, which is essentially a biological problem. The people at Hampton are emphasizing equally the physical problem, — the removal of solids. And the other problem, the filter problem, has been emphasized strongly by experience at the Technology station. We have a new filter there now which has been running for about a year. Three years ago we started a trickling filter and ran it for about a year. For the first six or eight months it gave us poor results. Then the summer came, and with the warm weather the nitrites began to go up very sharply. Some nitrites had formed before that, but after the extreme excess of nitrites and with the advent of warm weather the nitrites fell off and the nitrates increased, and after that the filter did splendid work for a year and a quarter. We took this filter apart and built another, and the history of the second is almost exactly the history of the first. In the spring the filter did poor work. But in the warm weather the organisms that make nitrates got to work and now the nitrates are beginning to go up and the nitrites are stable. It seems to me there is a very distinct biological cycle. I hope we shall soon have an opportunity to start a filter at another season so that we shall be able to see whether that long, latent period before the organisms that make nitrates get to work is really necessary. At any rate, that problem of rendering the organic matter stable is very well in hand. And the problem of bacteria removal is pretty well in hand. I think it is generally recognized now that that can be accomplished efficiently and economically by the treatment with chloride of lime. I hope that one of the next victims to-night may be Mr. Whitman,

in order that we may hear something of what they are doing in this line in Baltimore. The problem of the removal of solids is surely the great puzzle of sewage work. It is, therefore, particularly interesting to hear of the attempts made to solve that problem, and particularly of one of the most promising means, the spread of this Hampton idea as shown in the Essen tanks. For all these things we owe a great debt to Mr. Clark and Dr. Kinnicutt for what they have told us.

Mr. Whitman. — Professor Winslow has just spoken of the disinfection of sewage and sewage effluents by means of chlorine, and in his remarks about the presence of one very familiar with this work, I presumed he referred to the pioneer in this line of work in America, Professor Phelps, of the Massachusetts Institute of Technology. During the past year we have, with the collaboration of Professor Phelps, carried out in Baltimore, at the Walbrook Sewage Testing Station, a series of experiments on the disinfection of sprinkling filter effluents with solutions of commercial bleaching powder. Our results have been extremely satisfactory, so satisfactory in fact that our final plans for the sewage disposal works at Baltimore will include a chlorine disinfection plant.

In order to give you a clearer understanding of our work in Baltimore on the disinfection of sewage effluents, I will first give a brief description of the sewage testing station which was established at the beginning of the active work of constructing the sewers and sewage disposal works soon after the present Sewerage Commission was organized.

At that time there was no sewer or system of sewers from which sewage could be taken for experimental work as was done at Columbus. There were a number of storm-water drains into which, when they were first constructed, no house sewage was allowed to drain, but which have been tapped more and more frequently by private drains and house connections, until a number of them carry large amounts of house sewage. None of these were located, however, in parts of the city where a large scale testing station could be located, and it was decided to build sewers in one of the suburbs, Walbrook, where a suitable location for the testing station could be built. This called for laying of about 13 000 ft. of sewer in connection with the testing plant.

The primary objects for which the testing station was constructed were to determine the depth of bed and the size of stone required to give the high degree of purification called for by the

local conditions in Baltimore at the main disposal works. The testing plant itself consisted of a settling tank, twelve sprinkling filters and twelve sedimentation basins through which the effluents from the sprinkling filters passed. A detailed description of the plant can be found in the *Engineering Record* of November 17, 1906. The twelve filters were constructed so that four were 6 ft. deep, four 9 ft. deep, and four 12 ft. deep. The four beds of each of these depths were constructed of different sizes of stone, making a bed of each depth constructed of the same size of stone. These four sizes of stone were $\frac{1}{2}$ to $1\frac{1}{2}$ in., 1 to 2 in., 2 to 4 in., and 4 to 6 in.

In addition to this testing plant a laboratory building was constructed and equipped for chemical and bacteriological analyses of the sewage and effluents. Operation was begun at the station on August 1, 1907, and the chlorine disinfection work started in November of the same year.

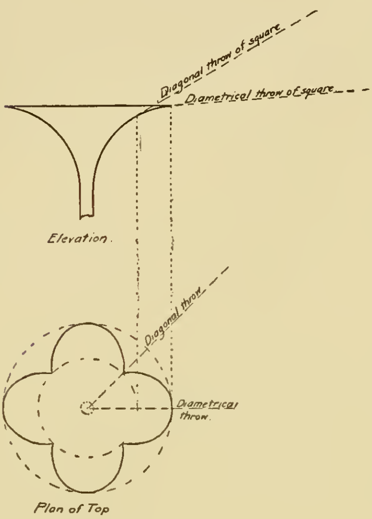
Our first experiments in the disinfection work were with the effluent from the filter 12 ft. deep, made up of the $\frac{1}{2}$ to $1\frac{1}{2}$ in. stone. This effluent, before disinfection, was practically always stable as shown by the methylene blue test, and contained an average of from 100 000 to 150 000 bacteria per cu. cm. In our experiments the quantity of available chlorine added to the effluent varied from less than 1 to about 4 parts per million. By the use of 3 parts per million the total number of bacteria in the effluent was reduced to from 1 000 to 10 000 per cu. cm., while the red colonies on litmus lactose agar were reduced 98%, and the reduction as shown by lactose bile and lactose broth were both over 90%.

In the spring of 1908, as our results seemed to indicate that 1 to 3 in. stone would be the best size for practical results, a change in the testing plant was made and four beds of this size stone, of depths of $4\frac{1}{2}$, 6, $7\frac{1}{2}$ and 9 ft. were constructed. The effluents from each of these beds are now being disinfected with chlorine, and we hope to determine by these studies if it will be possible to secure an effluent as well purified and as stable from a shallow bed treated with large quantities of chlorine as can be obtained from a deeper bed treated with a small quantity of chlorine. The results of these experiments have not as yet been carefully studied.

The objection raised by Dr. Clark to the unequal distribution over sprinkling filter surfaces by means of fixed nozzles is a serious one, but I hope we shall be able to overcome this in our Baltimore work where fixed sprinkling nozzles will be used.

Our nozzles will, I believe, be very different from any now in use in any disposal works. A nozzle similar to the one we propose to use was devised and used experimentally by Mr. William Gavin Taylor at Waterbury, Conn. A description of the nozzle was published by Mr. Taylor in the *Engineering News.*

This form of nozzle will give a spray the perimeter of which as it falls on the filter surface is approximately a square, the sides being fairly straight and the corners of the square somewhat rounded. The means by which this square spray is obtained is best explained by the accompanying sketch.



CONE FITTING IN NOZZLE ORIFICE

In our experiments we used wooden cones and cut them back to obtain the diagonal throw. We found that a large cone about 5 in. in diameter gave a much more satisfactory square under varying heads than could be obtained with the smaller cones.

Not only will the square spray form of nozzle be used, but the head on the nozzles will be varied in short periods of about five minutes, so that the maximum head will throw a spray covering a 15-ft. square while the minimum head will cover a 2-ft. square. This variation in head will be brought about by a butterfly valve revolving in the main distributor to each bed. The rate at which this valve revolves will be so regulated that every portion of the area between the 2 ft-square and the 15-ft. square will receive the same amount of sewage. That is to say, that in a 15-ft. square or in 225 sq. ft. the entire surface except 4 sq. ft. in the center, or over 98% of the surface, will receive sewage at a uniform rate.

Many interesting points in sewage disposal have presented themselves in the operation of the testing station and the design of the main disposal works, but before these are published we hope to be able to point to practical results.

PROFESSOR KINNICUTT. — How many parts of chlorine did you say?

Mr. Whitman. — From one to three parts per million of chlorine.

Mr. Robert Spurr Weston. — I would like to ask Mr. Clark if he has investigated the centrifugal machine as a method of sludge removal. I intended to go to see a plant in operation at Harburg, but unfortunately I could not. I was told that another plant was being built at Hanover, and I would like to ask Mr. Clark if he saw or heard anything about that?

Dr. Clark. — I got all the literature the centrifugal people have put out, and intended to visit the Harburg plant, but while I was at Hamburg I was told that it was not in operation at that time, so I didn't go to see it. I understand, however, it is in operation most of the time.

A Member. — Do you understand it is operating well?

Dr. Clark. — Yes, I think it is operating well. At the experiment station at Berlin I was told that it was giving very good results at a low cost considering the work done. But whether that statement was based upon experimental operation or operation at Harburg, I am unable to say.

Mr. Patten. — I should like to ask one question in regard to the large areas used for the disposal of sludge. Is it anticipated that those areas can be used in the immediate future, or at any time, for any other purpose?

Mr. Clark. — Yes, I think it is. Certainly at one place these areas are being used again. At York there is a large and handsome field that is simply a mass of buried sludge. The sod and soil are removed to the depth of one foot, then a layer of sludge 9 or 10 ft. deep is deposited and the soil and sod put back over it, making a field with a higher grade, but still a handsome field.

Mr. Patten. — And then go to a new field?

Mr. Clark. — Yes.

Mr. Patten. — Ever go back to the first field?

Mr. Clark. — No.

Professor Kinnicutt. — The same thing is being done at Leicester.

Mr. Fales. — When Mr. Clark spoke of this sludge at Birmingham on which neither grass nor weeds would grow, it occurred to me that that is what we thought when we pumped our chemically treated sewage sludge on to beds. They seemed at first to be a barren waste, but after a few years the grass began to grow and at the present time an enormous crop, or really three crops, are being cut from those old sludge beds. That is, the action

that has taken place on standing has been such as to induce this enormous growth of grass.

Mr. Clark. — I might say that in one or two other places, where there are both septic and chemical precipitation tanks, there was nothing growing on the sludge from chemical precipitation, after a year or more in place, whereas there was a rank and heavy growth of grass on septic sludge of equal age.

Mr. Fales. — We began to haul this sludge down on to the dump in 1899. Part of the swamp there has been filled in and the sludge has been standing for two or three years. We rented that land to parties living in the vicinity, and they farm it, trying various crops on that and the part of the dump which has been completed. A few years ago they tried potatoes and got a very good crop, but the potatoes were very scabby. But last year they tried another variety of potato and the results were certainly very surprising. I never saw larger or better potatoes growing anywhere than they produced from this sludge.

A Member. — As to size or flavor?

Mr. Fales. — As to size and quantity. I have no doubt the flavor was all right.

Mr. Weston. — We are indebted to Mr. Clark for a very valuable array of facts, and to Mr. Kinnicutt for his interesting discussion, and for his account of his own observations abroad. I think this question of removal of solid matter is one closely connected with the condition of the sewage before it gets to the disposal works. I think when comparing one sewage disposal plant with another we are apt to fail to take this into account. If the sewage is fresh and the suspended matter can readily be removed in the laboratory by simple filtration, it is in a condition to be removed by a comparatively short period of sedimentation in a settling tank. On the other hand, if the sewage has been comparatively a long time in the sewer and the suspended matter has become converted into colloidal or semi-soluble material by long-continued agitation, it doesn't seem that any system of sedimentation can be very efficient.

Regarding the distribution of sewage on trickling filters, I had the good fortune to visit the experimental plant at Leipsic last January. There the experts have been making experiments for three or four years on a small scale and later on quite a large scale, on beds 17 ft. wide by about 70 to 100 ft. long, and while the nozzle sprinkler has given a satisfactory distribution of sewage, they have obtained

equally good results with a distributor of the Barker-mill type, and even better results with the simple tile pipe distributor, such as was used in the old contact filter beds. These are simply tile laid with open joints at short intervals — I think 8½-ft. intervals — the pipe being taken up occasionally and cleaned when the joints become clogged. They also made some experiments with filling material for trickling filters and found that equally good results could be obtained with almost any kind of material, providing the size was uniform and suited to the sewage to be treated; that is, the broken stone, the furnace cinder and the copper smelter cinder all gave equally good results. But where the material was mixed, the coarse with the fine, a tight membrane formed on top of the filter, and caused the shutting off of air and the other bad effects mentioned by Mr. Clark. The effluent from this experimental filter in Leipsic was very good indeed. The sewage was simply settled in a grit chamber, with about six or seven hours' sedimentation, as I remember it, and the effluent from this passed on to trickling filters. It is hoped to obtain experience enough in this experimental plant to completely purify the whole sewage of Leipsic which is now discharged into the river after a short preliminary treatment.

Mr. Phelps. — Two points raised here to-night interested me particularly. The first is this matter of distribution. I agree with Mr. Clark fully that a great deal of our trouble comes from imperfect distribution. I have had that brought to mind in a striking way in making calculations of some of our sprinkler efficiencies. It seems to be a fact that with a good distributor — nozzle of the Columbus type, operating intermittently — giving what we call a good distribution, a considerable portion of the filter is being operated at rates four, five or more times the mean rate; that is, at rates of 10 000 000 or 12 000 000 gal. instead of 2 000 000 gal. Of course, the direct effect must be to overload those immediate areas with any suspended matter that may be contained in the sewage, and, eventually, to clog such areas. Then the sewage overflows into adjoining areas, clogging those, and so the building up of the clogged areas goes on until the whole surface becomes clogged. I don't think the solution is going to be along the lines of mechanical sprinklers unless we are prepared to adopt the suggestion of covered tanks, because those are bound to accumulate ice and go out of commission. I think the solution is to be sought along the lines Mr. Whitman has laid down, — a sprinkler that gives a square

instead of a circular spray, — so we shall not have to build expensive circular beds which will give us a distribution in a thin line in the perimeter instead of over an area, and then combining with that system an intermittency which will make that perimeter move in and out from the center to the periphery. Here is a striking illustration of the difference between good and poor distribution. We are experimenting with two filters running at the same rate, but with different distributors, one being an overhead distributor of rather poorer efficiency than the other, which is a Columbus distributor operating intermittently. The clogging under the poor distributor has been quite marked, though not enough to make us abandon the experiment, or to make it impractical with care and attention. Still it has necessitated digging over the surface twice, I think, within a year. On the other side the Columbus nozzle, giving us perhaps the best distribution we are able to get at this time with a circular spray, shows no signs of clogging.

The other point that interested me is that of the Hampton and Essen system of concentrated sludge treatment. It has seemed to me that in concentrated masses the organisms in the organic matter kill themselves out. It seems to be a matter of observation that sludge will not take care of itself so well in concentrated masses as when it is washed by the solution above it. We haven't any great amount of experimental data on this point, but I am strongly inclined to believe that the solution is going to be along the opposite line of keeping the sludge washed, so that the products of the reaction are carried off instead of being concentrated. In that way the action will be accelerated.

Mr. Harrison P. Eddy (*by letter*). — I have been very much interested in reading Mr. Clark's discussion of his observations upon sewage purification works abroad, and feel that the Society is very fortunate in having first hand the results of the studies of so competent an observer.

It is interesting to note that chemical precipitation — a method of sewage treatment which has been so severely and perhaps not wholly unjustly criticised in this country — is still in use in very many places and at plants of considerable magnitude. The ease of operation, the comparative simplicity of the processes involved and the freedom from the uncertainties attending most other methods of sewage treatment are appreciated by comparatively few engineers. The operation of this and other methods side by side quickly demonstrates this fact. When the floods descend upon snow-covered, partly frozen or seriously

clogged sand filters is the time when the works manager appreciates his opportunity to put in a few extra pounds of chemicals and allow the sewage to flow leisurely through the settling basin of his chemical precipitation plant. Unfortunately comparatively few of our cities are so situated that sewage treated in this way is sufficiently purified to be discharged into the available water courses.

The large number of municipalities which have found their earlier works inadequate and which are making radical changes in their methods demonstrates the wisdom of going slow in matters relating to sewage disposal. How often has a panacea for the ills of sewage discharge been heralded? Beginning many years ago with certain chemicals, as mixture of chemicals and inert substances, and coming down through the long line of discoveries to the septic tank, yet all have been found to be more or less wanting under some circumstances.

The wisdom with which our own State Board of Health has acted during the past twenty years is demonstrated no more clearly than in its conservative handling of the sewage disposal problems in many of the municipalities of this state. Often it has waited patiently, year after year, for some action to be taken, some progress to be made, but always exerting a steady, uniform pressure toward better conditions. This policy has, no doubt, prevented many mistakes and has permitted the board to maintain a highly respected position.

One cannot but be impressed with the magnitude of the sewage disposal works and of the expenditures made to solve these problems in England. Some of the individual plants have cost about as much, if not, indeed, more than all of our plants together.

We should not lose sight of the fact, and I believe it is a fact, that the conditions which have been encountered in Massachusetts are vastly more favorable than those which have surrounded our English contemporaries. It is hardly fair, for instance, to compare without many qualifying statements the results obtained at Manchester or Birmingham with those at Brockton and Framingham, — the one dependent upon works artificially constructed throughout, and dealing with immense volumes of sewage as well as of storm water; the other having at hand natural areas of sand of proper quality and dealing with mere driblets of sewage. A higher degree of purification has been obtained here, to be sure, but it is a question if the results obtained abroad have not required greater skill and greater ingenuity.

Mr. Clark emphasizes the fact which I have so often pointed out, that the suspended matter in the sewage causes the principal difficulties, and I belive this is equally true of all methods to-day employed for the purification of sewage.

One feature in which foreign disposal problems differ from many of those in America is that of the disposal of storm water. I had hoped Mr. Clark would deal with this question, which is most interesting and exceedingly important. In some cases in this country it has been believed to be necessary to build separate systems of sewers and drains to provide for a separation of the sewage and storm water now carried by a more or less complete combined system of sewers. Some progress has already been made along these lines, although the expense involved is enormous. In England, I understand that many of the disposal works provide for the treatment of a portion of the storm flow, and it would be very interesting to know what provisions are made for this treatment, what the results upon the rivers are, and if it is there believed that it will not eventually be necessary to separate storm water from sewage.

The very complete data relating to costs, materials and analyses given in Mr. Clark's paper make it a very valuable production for reference.

Mr. Clark. — I should like to say a word or two in conclusion. I am always glad to hear good reports from Dr. Kinnicutt of the Hampton tank because Dr. Travis who started this tank stated that it was based upon Lawrence work; in fact, he published a long article upon this fact, giving due credit to Lawrence; and Baker, in his book on "British Sewage Disposal," extracts several pages from this article.

As regards what Professor Phelps had to say of septic tanks, I also believe that the most favorable conditions under which sludge can be kept in a septic tank to insure destruction are as he states them, but I was not speaking so much about the destruction of sludge, as of the concentration of sludge. The Essen tank and, I think, also, the Hampton tank, although I am not particularly well acquainted with the latter, concentrate the sludge so that it contains only a comparatively small amount of water. That was the point I made in regard to this Essen tank. Enough sewage enters the sludge portion daily, I believe, to insure good septic action. In regard to the distribution of sewage upon sprinkler filters I only wish to suggest that, if perfect distribution can be obtained, a much smaller area will purify a unit volume of sewage satisfactorily than a larger area over

which the sewage is imperfectly distributed, as by the Birmingham and other types of nozzle working under a constant head; that is to say, if you can purify 4 000 000 gallons of sewage on an acre by perfect distribution even by distributors that would not work in cold snowy weather, it might be cheaper to cover that area than to construct an uncovered area twice as great for the purification of the same volume of sewage.

In regard to Professor Winslow's discussion on the formation of nitrates, I can only call his attention to the fact that this was very thoroughly discussed in the first report of the Lawrence Experiment Station written by Mr. Mills nearly twenty years ago, and that it has been shown many times at the Lawrence Experiment Station that filters started in cold weather will not nitrify until warm weather begins, while filters started in warm weather will begin to nitrify in a very few days. I can call Professor Winslow's attention to a table given by Fuller in the Lawrence Experiment Station report for 1894, page 475, where the data in regard to period of pre-nitrification of twenty-seven filters started between 1887 and 1894 inclusive are given, showing the period elapsing before nitrification began to vary from four to one hundred and fifty-five days, this being dependent upon the material of the filter, method of operation and time of year when started. I would also call his attention to the fact that a sprinkling filter started at the Experiment Station in May, 1899, and operated at a rate of 2 000 000 gal. per acre daily, contained over two parts of nitrates per 100 000 at the end of three weeks' operation.

In regard to what Professor Kinnicutt had to say of the slate contact beds of Dibdin, I wish to state again that I am only quoting from the recent report of the Royal Commission when I say that the results of these beds are anaërobic rather than aërobic just as was the result of a similar slate bed operated at Lawrence nearly nine years ago, and discussed in the Lawrence report for 1901. I should like to discuss the storm water question brought up by Mr. Eddy, but beyond getting the maximum and minimum flows at a number of areas and finding that at some areas the maximum flow is cared for and at others not, I gathered little data. The difference between maximum and minimum flows is of course slight compared with American figures, owing to the more frequent but much less heavy rainfalls.

I wish also to state, as I have before, that I do not agree in all respects with Dr. Kinnicutt's statement that bacterial perco-

lating filters had their origin in England. In this I am simply in accord with many of the best English investigators and experts along this line. There is no doubt that the contact filter of Dibdin is an English product. What, however, were the filters operated at Lawrence from 1892 on, constructed of stone, coarse clinker, coarse coke, etc., dosed many times a day and receiving sewage at the rate of from half a million to one million gallons per acre daily, but percolating filters? To be sure the sewage was not sprayed on, as on some of the municipal plants in England. The materials, rates and the results of these filters, however, were similar to the materials, rates and results of many of the so-called municipal sprinkling or percolating filters in England at the present time. I must also call attention to the fact that many of these sprinkling or percolating filters in England are operated in about the same way that these early percolating filters at Lawrence were operated — that is, intermittently; dosed once an hour for a short period and then a period of rest and again dosed. In order to show that English sewage experts do not all agree with Professor Kinnicutt in this respect, but with the statements that I have made here, I will call attention to a statement by that well-known expert, Scott-Moncrieff, in an article in the English periodical, *The Surveyor and Municipal and County Engineer*, of October 9, 1908, where he says, —

"The vogue of the contact bed is a case in point. It was introduced with no kind of scientific justification, and in this respect was quite different from the percolating filter, which obviously embodied the conditions required for the work of the nitrifying organisms in a much more satisfactory way, and had already been the subject of careful investigation in the United States."

[NOTE.— Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by February 1, 1909, for publication in a subsequent number of the JOURNAL.]

OBITUARY.

Irving Tupper Farnham.

MEMBER BOSTON SOCIETY CIVIL ENGINEERS.
DIED SEPTEMBER 19, 1908.

IRVING TUPPER FARNHAM, son of Charles and Julia (Tupper) Farnham, was born in Deposit, Delaware County, N. Y., August 21, 1869. While still quite young he worked at lumbering and upon a farm. Preparing at Deposit Academy, he entered the College of Civil Engineering, Cornell University, in 1888, and graduated in 1892, with the degree of Civil Engineer. The esteem in which he was held by his professors may be inferred from the fact that he held the position of librarian of the Civil Engineering Library during his last two years in college. After graduation he entered the Elmira Bridge Works in the draughting department, but, seeing better prospects in a position offered him on the force of the city engineer of Newton, the late Albert F. Noyes, left Elmira to take up that work in June, 1892. Here he obtained a practical training in an extended variety of municipal work, first as instrument-man on the drainage work of the so-called Cheese-Cake brook improvement; then on surveys for the assessors' block-system, and on the Hammond Pond drainage survey for the board of health. In 1894 he was put in charge of the field work connected with the surveys and construction of sections 1 and 2 of the Newton Boulevard, as division engineer, with a field office at Chestnut Hill. When this work was completed he was assigned to a similar position on the Washington Street widening and the abolition of grade crossings on the north side of the city. In 1898 he was in charge of the surveys of South Meadow brook improvement and the preliminary studies for abolition of grade crossings on the south side. After this work was plotted and reported on, the forces of the office were considerably reduced, and Mr. Farnham accepted a position as principal assistant engineer with the Massachusetts Highway Commission.

His services with the Highway Commission extended over a little more than a year, from February 6, 1899, to April 14, 1900. In this work his experience in the construction of Beacon Street and Washington Street boulevards in Newton proved of

much value to the commission, and the commission regretted greatly his departure.

In April, 1900, after the resignation of Mr. Henry D. Woods as city engineer of Newton, Mr. Farnham was appointed his successor and entered upon the much larger responsibilities of the oversight of all the engineering work of the city of Newton. This position he held until the time of his death.

Among the most important pieces of work carried out under his direction, the following may be particularly mentioned: In 1900 extensions of the main sewers along the banks of the Charles River towards Newton Upper Falls, and in 1901 a further extension under the bed of the Charles River at Echo Bridge in tunnel to Elliot Street. During this latter year also plans were made for a second section of the covered reservoir on Waban Hill and work upon its construction was begun, although it was not finished until the following year. In 1902 the sewers were further extended towards Newton Highlands and Chestnut Hill. These extensions, as well as some of the previous ones, involved tunnels under the Sudbury and Cochituate aqueducts of the Metropolitan water works, which had to be executed with the greatest care. An agreement having been reached with the Boston & Worcester Railway Company, that company began in 1902 the widening of some three miles of Boylston Street, on which the city of Newton put in the drains and catch-basins by day work, all under Mr. Farnham's direction. At this time he also designed and constructed a small auxiliary pumping plant for a sewer district at Newton Upper Falls which was below the level of the main sewer. In 1903 the work of abolition of grade crossings on the south side of the city was taken up with the Boston & Albany Railroad, and construction work was begun, all the changes of streets and drains being made by the city of Newton under Mr. Farnham's direction. The proper drainage of the depressed tracks required the lowering of long stretches of brooks and drains, besides some changes in the sewers. In 1906 Mr. Farnham designed and constructed a new concrete bridge over the Charles River at Newton Lower Falls, replacing the old red bridge to Weston.

In addition to the foregoing items, which are perhaps most worthy of detailed mention, there was the usual large amount of minor work which is always found in a city like Newton, and which received from Mr. Farnham the same conscientious and painstaking attention.

He was always a student and spent much time in investi-

gating all the details of plans and construction work which were in hand. He was ever pleasant with his associates and interested in their welfare. He took a great interest in the work of the Boston Society of Civil Engineers. He was a director of the society, clerk of the Sanitary Section, and chairman of the Committee on Run-Off of this section at the time of his death. He had taken an especial interest in the question of run-off from sewered areas and spent a great deal of time in its study.

Mr. Farnham was also a member of the American Society of Civil Engineers, the Massachusetts Highway Association and the New England Water Works Association. He had taken a particular interest in the affairs of the Highway Association and was its president in 1904. The following quotation from the resolutions passed by the Highway Association well expresses the esteem in which he was generally held:

> "A man of character above reproach, an official of most devoted and thorough attention to every detail of his duties, a professional man whose grasp of difficult questions was sure to yield a convincing argument for or against the proposition involved, and whose courage never permitted him to lower the standard he had raised as a governing principle in his work, he had achieved an enviable position as a competent, safe and practical engineer, and there seemed no bar to greater success in his career.
>
> "Too close application resulted in bodily affliction and breaking under the strain, and (we quote the language of his pastor at the funeral) 'sudden darkness came upon his mind, and in that moment of darkness, knowing nothing; he died.'
>
> "His birth, school and college days, as a preparation for his future, and the time of his death are of your official records, and we add now a tribute to his memory, as of a man worthy to be followed in qualities which make for high purpose, purity of life, perseverance under difficulties and an abiding trust in the Eternal Wisdom, which made and controls the earthly existence and the destinies of men."

Mr. Farnham was a member of the Congregational Church in West Newton and much interested in its Sunday-school work. He was married on March 27, 1892, to Miss Jennie A. Carroll, who, with four children, survives him.

He was elected a member of this Society on March 17, 1897.

Charles W. Sherman,
Henry D. Woods,
Charles W. Ross,
Committee.

Editors reprinting articles from this JOURNAL are requested to credit the author, the JOURNAL OF THE ASSOCIATION, and the Society before which such articles were read.

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

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ENGINE TERMINAL FACILITIES CONSTRUCTED BY THE WABASH RAILROAD COMPANY AT DECATUR, ILL.*

BY A. O. CUNNINGHAM, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read before the Club, May 20, 1908.]

THE Wabash Railroad Company has lately spent a large amount of money in improving engine terminal facilities at Decatur, Ill. This place is situated very nearly half way between St. Louis and Chicago, and is at the junction of the Springfield and Decatur divisions of the Wabash Railroad. The Decatur Division extends from St. Louis to Chicago, from Bement to Tilton, and from Bement to Altamont, and comprises 460 miles. All trains from St. Louis for points north and east pass through Decatur, so that this engine terminal is the most important on the system. There are approximately one hundred engines cared for here per day.

Previously to these improvements, engines were housed in an old and dilapidated building which had been in service over twenty-six years at the time when the improvements were commenced. The old engine house was too short for up-to-date engines, and the stalls consequently had been lengthened out to properly house the new engines. These extensions were generally made of wood. A new turntable was installed about six years ago, designed to fit the old foundations of the older turntable, and consequently its depth was not sufficient, with the result that there was usually too much deflection, requiring more power

*Illustrations of this paper are furnished by the courtesy of the *Railroad Age Gazette.*

to turn it than should have been necessary. It was operated by a 9 h. p. gasoline motor and did the work fairly satisfactorily.

Coal for the engines was obtained from a coal mine in the Decatur yard, which had a few chutes to accommodate the engines. A dilapidated machine shop, built on, piecemeal, to the old engine house, took care of the repairs to engines, and an old-fashioned cinder pit for taking care of the cinders from the locomotives completed the facilities at that time. Because of these poor facilities, together with the limited room and consequent congestion, the cost of handling engines was exceedingly great.

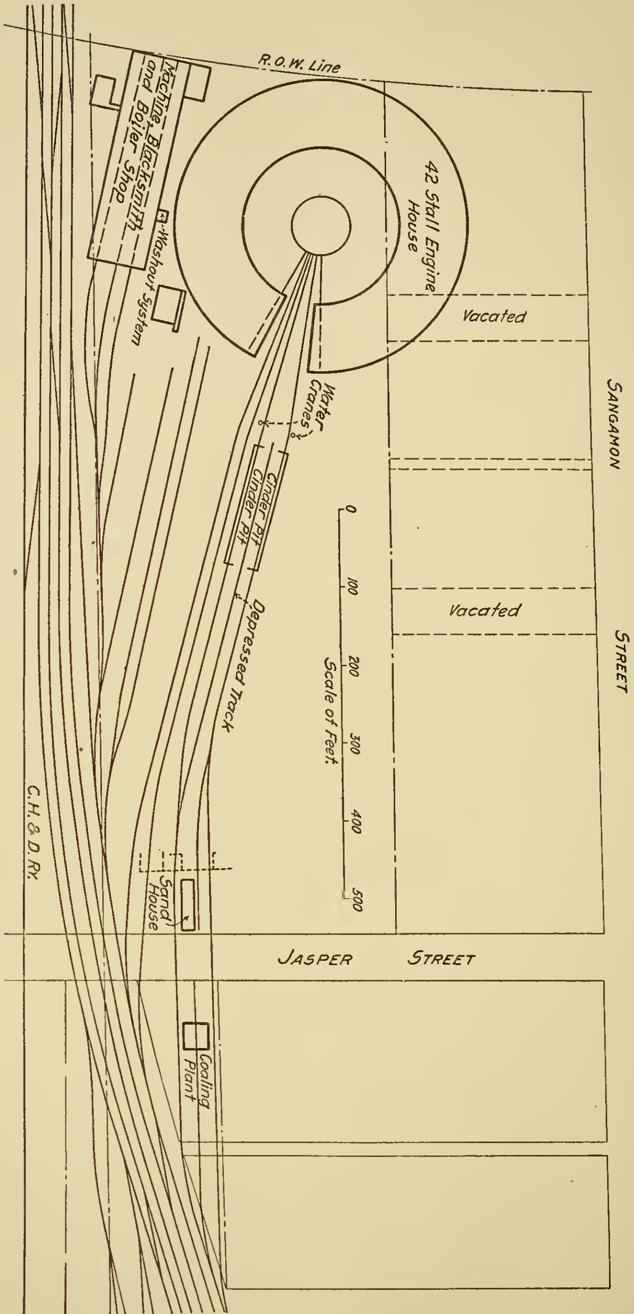
About two years ago improvements were started to rectify these defects and to lessen this cost. The first structure which it was necessary to build was the coaling chute, as the coal mine which formerly supplied the engines had practically given out. This coaling plant was constructed of timber on concrete foundations. It was designed with an elevated pocket that would hold 200 tons of coal, from which the engines could be coaled from ordinary movable aprons, and was constructed by the Fairbanks-Morse Company. Coal is brought to the chute in bottom-dump cars and is dumped into a concrete hopper beneath the track. From this hopper it is emptied under control of the operator by gravity into hoisting buckets through an orifice in each of the two side walls of the concrete hopper. There are two of these buckets, each with sufficient capacity for holding a ton of coal, and as one bucket is hoisted the other is lowered. The full bucket on reaching the top dumps automatically into the receiving bin. The whole plant is operated by an electric motor, controlled by one man, but two men in addition are necessary to empty the coal from the bottom-dump cars. It requires about two and one-half hours to fill the bin provided no engines are taking coal during that time. But since engines are continually being coaled, it is necessary to operate the plant about ten hours, the capacity of the bin being sufficient to take care of the coal required during the other fourteen hours. As the cost of handling coal through a coaling plant is not systematically computed, nor is there any standard method for keeping it, with the result that figures purporting to give it are useless, the following method is employed to determine this cost: The cost of labor, supervision, etc., for operating for a period of ten hours is $7. To this should be added depreciation charges, interest on the investment and cost of maintenance. The cost of the foundations and concrete receiving hopper was $1 225, and for the superstructure above foundation, $7 550, including

the motive power and machinery, making the total $8 775. The interest charge on this investment at 5 per cent. would be $438.75. The depreciation should vary according to the length of time the plant is in service, so nothing should be charged for this for the first five years, but thereafter, a charge of 5 per cent. per annum should be made. This means that the life of the plant is assumed to be twenty-five years. Maintenance charges will vary greatly and will increase as the plant grows older; 1 per cent. per annum should take care of this. Assuming these figures correct, then the cost of operating the plant will be $3 432.50 per year. As there are, on an average, 333 tons of coal per day handled by the plant, the cost for handling coal will be slightly less than 2.9 cts. per ton.

It should be noted that no charge has been made for switch engine service for transferring coal cars from the storage track to the depressed hopper. Such a charge would be proper, but could not be made in this instance, because this transference of cars is accomplished by yard engines which are compelled to take water in close proximity to this coal chute, and do this work directly after having taken water. Since the storage track is adjoining the coal chute, it would be impossible to make a proper charge for the small amount of work done by the switch engines in performing this service.

Usually in connection with a coaling plant there is installed a sand house for receiving and drying sand for locomotives, but as the sand house used with the old facilities was in good repair, it was moved to a new location and used in conjunction with the new facilities. It consists of a long oblong building with a tower at one end. The sand is brought in cars and unloaded by hand into the building, at one end of which is a sand-drying device, which is nothing more than a cast-iron barrel-shaped stove around which is fastened a very fine funnel-shaped screen. The sand is placed between the stove and the screen and on drying falls through the latter, after which it is shoveled into a hopper and driven by compressed air into the tower of the building. It falls by gravity from this tower through pipes which may be connected with the locomotives.

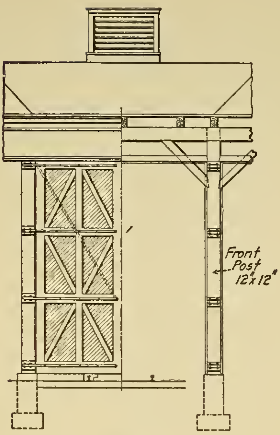
The next improvement was the construction of a new, up-to-date roundhouse with 42 stalls, new turntable and cinder pit, with all modern facilities for doing work cheaply. It might be claimed that the superstructure of this engine house is not up-to-date on account of its framework being of wood. However, there is but one other kind of material that could be used



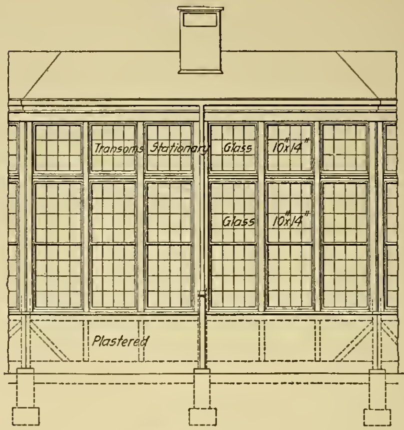
LOCATION OF 42-STALL ROUNDHOUSE.

in place of wood that would last any longer, and that is reinforced concrete. We all know that steel is soon rusted out where there is an abundance of smoke; therefore, steel unless properly protected should not be used in a roundhouse. Reinforced concrete construction is expensive, and, in the writer's opinion, not necessary because properly constructed engine houses with large timbers will last from twenty-five to thirty years, as smoke seems to preserve the timber. It is a waste of money to build such structures on Western railroads with the idea of making them everlasting, because these railroads are continually changing in their ownership and extending their lines, making it often advisable to change the location of their engine terminals and shops; and is it not also possible that railroads will be using electric motive power within a few years, requiring the reconstruction of engine shops and terminals? The only good argument for the use of reinforced concrete in buildings of this nature is the fact that it is fireproof; but there is so little danger of fire with a properly constructed engine house with heavy timbers that this argument need not be considered. In planning the construction of the new engine house, there were several things to be considered. First, it was necessary to do the work without interfering with the old facilities so that engines could be handled without loss of time. Further, there were three buildings in close proximity to the proposed site of the engine house which would work in with the arrangements of the new facilities. One was a boiler house about six years old, which could be used for heating purposes; another was a building of wooden construction, which could be turned into a machine shop, and the third was a two-story building which could be used advantageously for an office. It was finally found practical to so place the new engine house that these three old buildings could be utilized, and at the same time the new construction work could be carried on without interfering with the old facilities. As the Wabash had a year previously constructed large car shops in East Decatur, of which the operating power was electricity, and since there was ample current to spare from this plant, it was decided to use electricity to operate all the machinery and to provide light for the new terminal facilities.

The roundhouse is a complete circle, except for an opening sufficiently large to accommodate outbound and inbound tracks leading to the turntable. The house is of heavy mill construction, the timbers being of long leaf yellow pine. The construction is of the simplest kind, with posts between the stalls carrying the



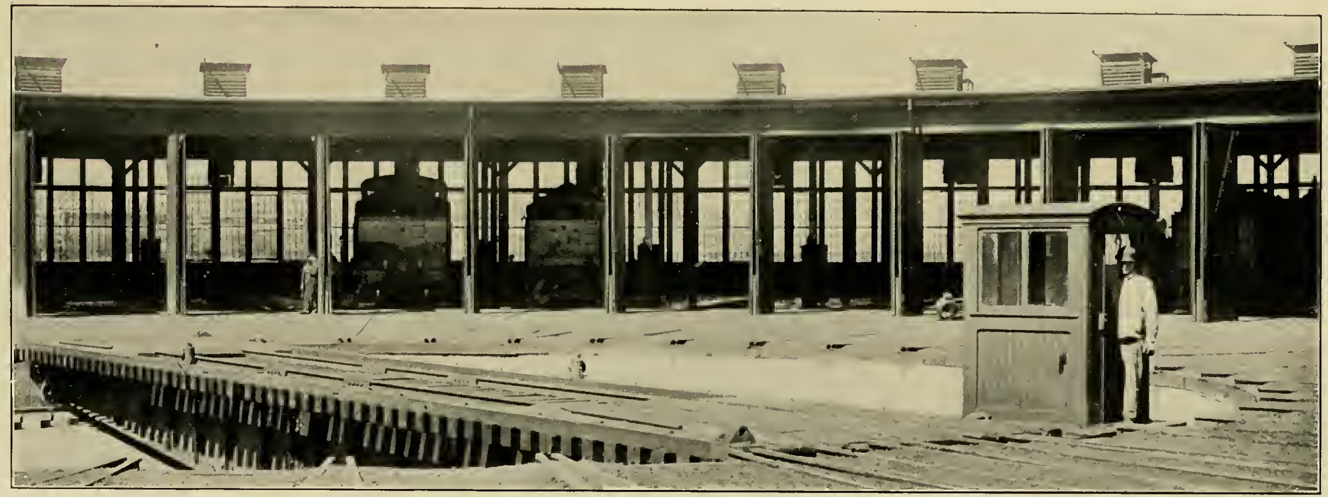
Front Elevation.



Rear Elevation.

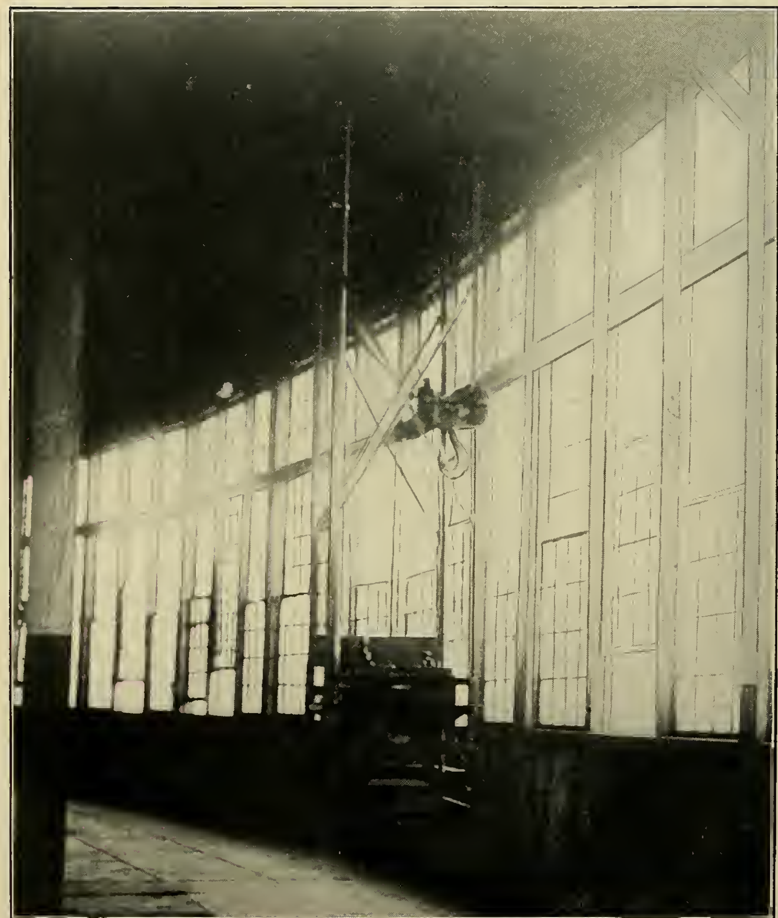
roof so as to cheapen its cost. The roof beams supported by the posts run crosswise of the engine pits, and the joists, to which the roof sheathing is nailed, rest on the beams and run lengthwise of the pits. This enables the smoke from the engines entering or leaving the house to follow the joists and find exit at the peak of the roof, at which point there is provided a ventilator over each stall, each ventilator being accommodated with a pivoted shutter, which can be opened or closed by a simple mechanism worked from the floor.

The walls of the building are constructed of wooden girts of the same width as the posts, and supported between them, to which is attached expanded metal, both on the inner surface and outer surface of the girts. The expanded metal on the outer surface is plastered on both sides with a mixture of Portland cement, lime and sand, and cocoanut fiber. The expanded metal on the inner surface is, of course, only coated on one side with the same kind of plaster. This construction provides a wall with a hollow space of air between, so that dampness cannot penetrate to the inner surface. The air space forms a good insulator to keep the building warm in winter and cool in summer. The plaster applied to these walls consists of one barrel of lime mixed with fifteen barrels of sand and four pounds of cocoanut fiber, the whole being mixed thoroughly with water and allowed to stand for at least two weeks so as to give the lime time enough to thoroughly slack. One part of Portland cement is then added to three parts of this mixture, with enough water added to make a plastic mortar. This is applied to the expanded metal and allowed to harden. This is called a scratch

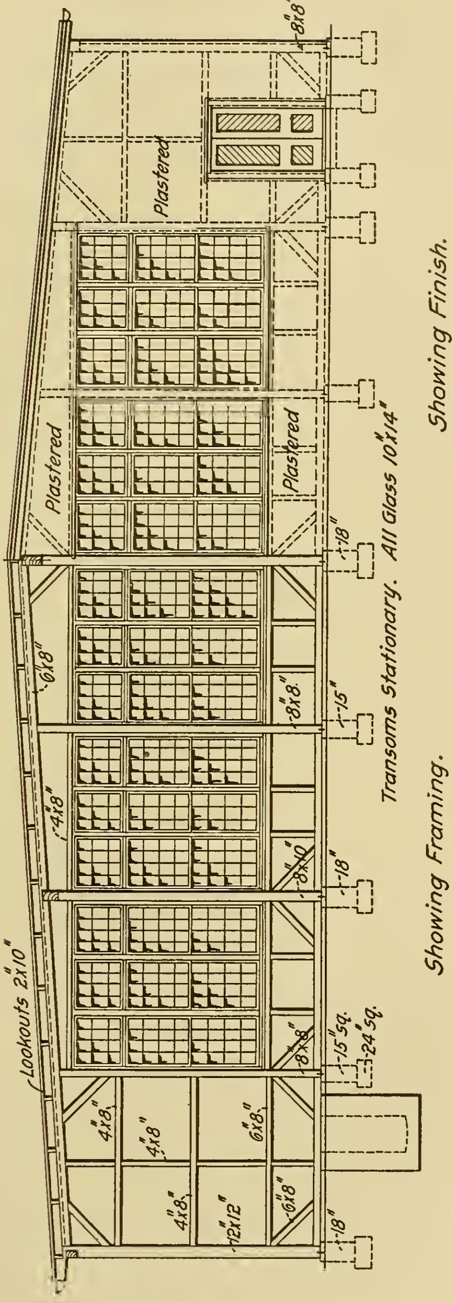


View of Inner Wall and Turntable; Wabash Roundhouse at Decatur, Ill.

Exterior, Showing Cement Base.



Telpher Hoist around the House. (See bottom p. 286.)



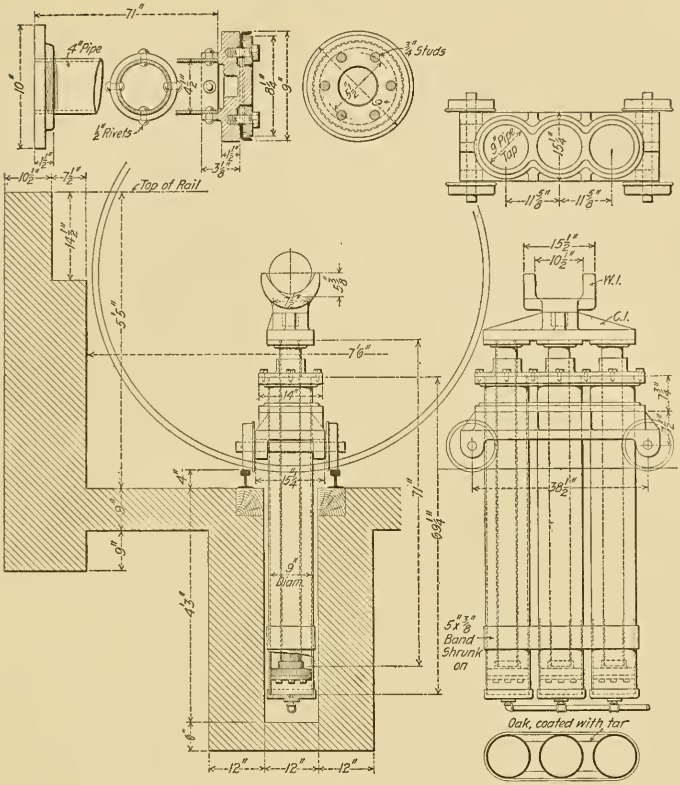
ELEVATION OF END WALLS OF ROUNDHOUSE.

coat. On this coat is plastered another layer of mortar, composed of three parts of sand to one part of cement. The plaster on the expanded metal on the outer surface of the house is $1\frac{1}{2}$ in. thick, and that on the inner surface about $\frac{3}{4}$ in. thick. This hollow wall extends completely around the outside of the house, and from the ground to a height of 5 ft. The exterior face of the wall is painted with a waterproofing compound. On this wall is placed a continuous line of windows, which extend to the underside of the eaves of the building, thus providing plenty of light, which is very essential in such buildings. The cost of a wall of this description is slightly less than brick, but a saving is made because brickwork requires foundations to support it, while this construction requires only those necessary to support the posts. Also lintels are required over openings in brickwork, and none are required in this kind of a wall. A further advantage in this construction is that a continuous line of windows may be used, while with brickwork this is not possible, on account of the pilasters. The windows are made so that the two lower sashes are hung together with copper chains over pulleys; thus when one is raised the other is lowered; consequently they are counterbalanced without going to the expense of providing box frames with counterweights.

The doors in the front of the building are made of yellow pine, substantially built and with no glass in them. They are provided with convenient hand-latching devices, which lock them at the top and bottom when they are closed. To keep them in an open position, when necessary, there are provided pieces of old rail set in a vertical position in concrete and placed radially with the door posts on the outside of the building, to which are attached hooks which engage in eyes in the door to hold them securely so as to prevent damage being done to them from high winds and by locomotives entering and leaving the house. At certain intervals the large doors are provided with smaller ones, so that the house can be entered by men conveniently from different points.

The pits are of concrete and constructed so that in jacking up engines, in order to remove the parts, the jacks rest on projections built on the walls of the pit; otherwise, the floor of the house would suffer.

On account of the liability of concrete in proximity to the rails to break up, due probably to the oil which drips from the engines, it was decided to fasten treated timbers on the walls of the pits and to spike the rails to them. It was estimated



PNEUMATIC JACK FOR DRIVING WHEEL PITS.

that the life of these timbers would be equal to that of the house, and, therefore, would be quite satisfactory.

Concrete foundations are provided to support the timbers on which the rails rest at the ends of the pits, and from the pits to the doors of the house, from which point to the turntable the rails are carried on ordinary track ties, under which cinder ballast is placed.

The pits open into a concrete duct, built entirely around the inner side of the front of the house. This duct serves the two purposes of draining the pits and carrying the heating mains, and is covered with checkered wrought-iron plates. In a convenient location of the house are constructed four driving wheel drop pits and two pony truck wheel pits. Over these pits the roof is carried by trusses, the posts being omitted so as to allow engine wheels to be moved between the pits and rolled out on tracks provided for them. One of these tracks connects directly with the machine shop.

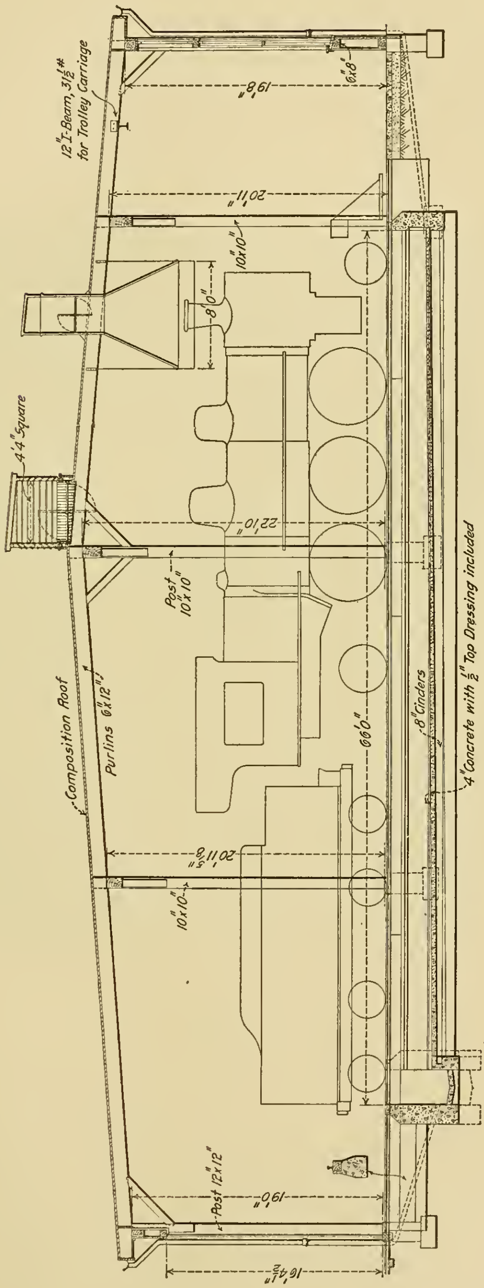
The floor of the roundhouse is of concrete, built similarly to a sidewalk, and placed on cinders. It is laid out in squares of about 3 ft. to the side, so if any square gets broken, as it is liable to be on account of the heavy pieces handled in a house of this description, it can be repaired at small cost.

The foundations carrying the posts are of concrete and are entirely separate from the floor, so if any settle, the floor will not be disturbed.

On the roof sheathing is laid a built-up roof of 5-ply tar and crushed limestone. The crushed limestone not only adds weight to hold the built-up roof in place, but, being white in color, helps to protect the tar from the rays of the sun. The cost of this roof covering in place was about the same as that of a prepared roofing.

One of the essential parts of an engine house is the smokejack to carry off the smoke from the engines standing in the house. So far, a satisfactory one has not been designed. Ordinarily, smokejacks are made of cast iron, which corrodes in a short time. Some of asbestos board have been tried, but they have not proved satisfactory. On this account it was decided to try a smokejack made of expanded metal attached to an iron frame plastered over with a mixture similar to that used on the walls of the building. The plaster covers up the ironwork entirely, and it is expected that a jack of this make will last a good deal longer than one of cast iron, with the advantage that it can be readily patched if it should become necessary. These jacks have now been in use for six months with no apparent damage to them. The only objection to them is their weight. If constructed with plaster $1\frac{1}{4}$ in. in thickness, they should weigh practically the same as cast iron. The style of jack best suited for a roundhouse is an inverted hopper leading to a chimney, the bottom opening of the hopper being about 3 ft. wide by 8 ft. long, to permit of the movement of engines two or three feet longitudinally from their proper central position, in order to get at their valves, etc. (See cut facing p. 291.)

In order to facilitate the handling of material from the roundhouse to the machine shop, a telpher hoist has been provided, running on an I-beam track, supported to the roof joists near the back of the house. This hoist is operated by electricity and will lift a load of two tons and carry it around the house at the rate of 300 ft. per minute, and in order to make it unnecessary to employ an operator continuously, a cage is provided, extending to within 3 ft. of the ground, so anybody can step into it from the floor and operate the machine. Some engine houses



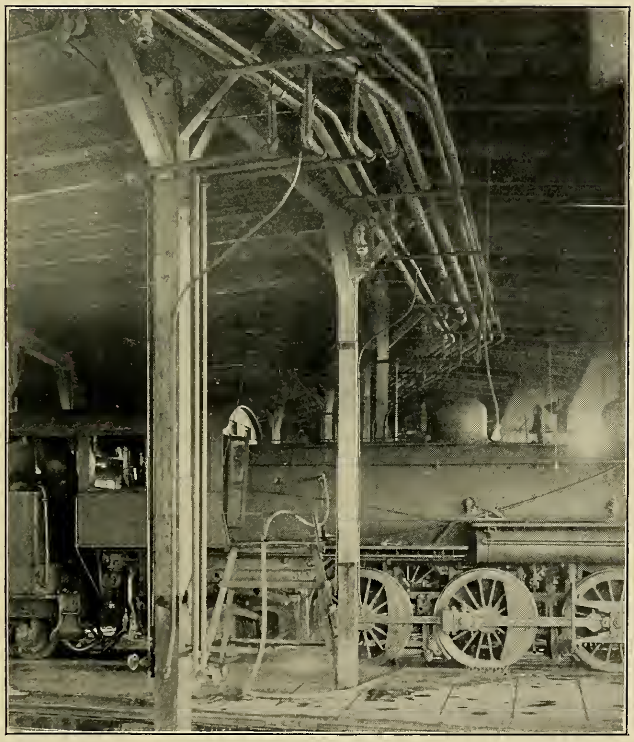
Cross-Section through Roundhouse.

have lately been constructed with a traveling crane with a capacity of 10 tons running around the outer circle of the house, and requiring an operator continuously, but as the maximum weight to be handled does not exceed two tons, the arrangement used in the Decatur house will do the work satisfactorily and at much less first cost, and with practically no operating expense.

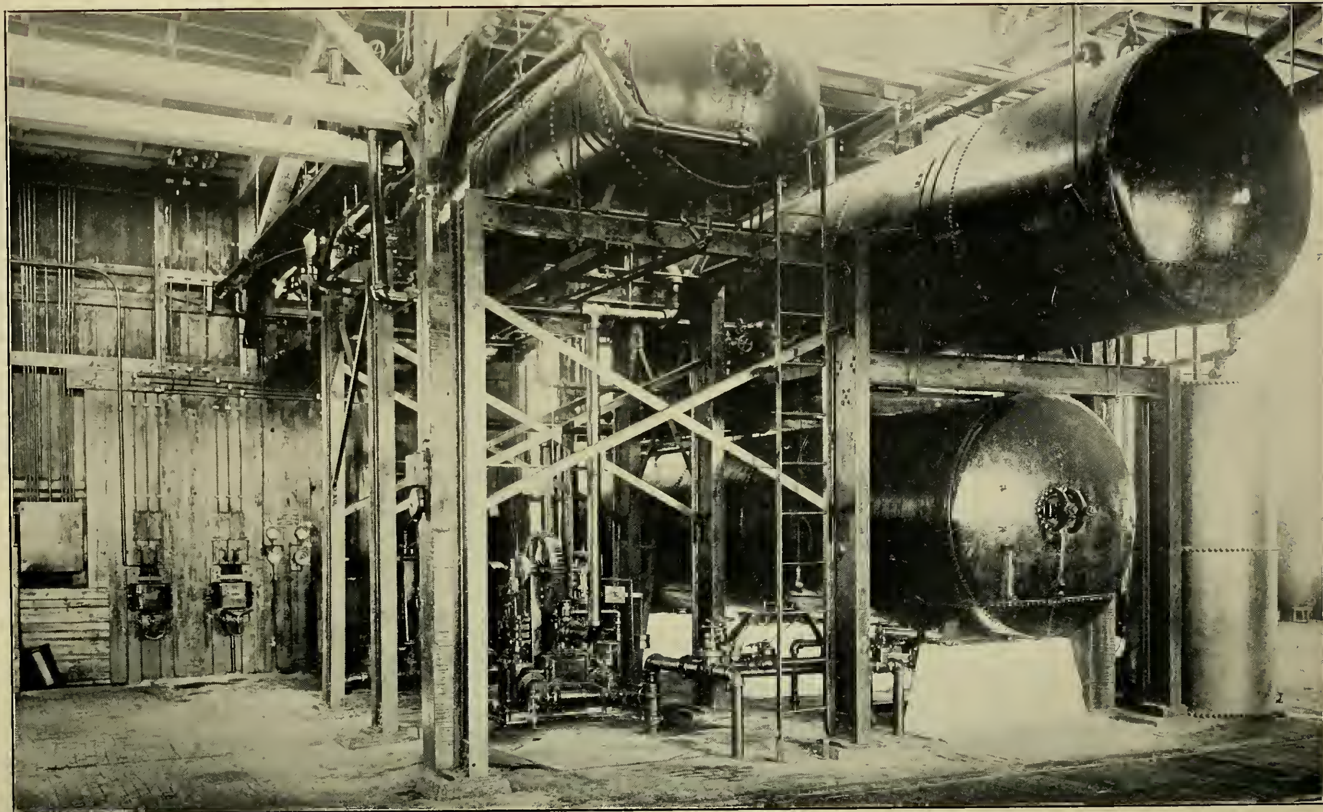
The water from the roof is carried off by downspouts and drained from the back of the house into the pits and into the duct from the front of the house. This duct empties into a catch-basin built on the outside of the house, which in turn is connected to the Decatur city sewer system by an 18-in. tile drain. The drop pits are drained by a 12-in. sewer pipe line connected with the 18-in. pipe line mentioned above.

The heating of the building is accomplished by a system of direct steam radiation, the steam being supplied from the boilers in the old boiler house. A 7-in. diameter main supply pipe with a pressure-reducing valve is connected to the boilers and runs underground to the duct inside the house, where it connects with a 5-in. diameter main branching both ways, and reducing to a 4-in. diameter pipe. This main connects with a system of four $1\frac{1}{2}$-in. pipe lines, which encircle the pits for radiating coils. These coils connect to a return system consisting of a $2\frac{1}{2}$-in. and increasing to a 3-in. diameter pipe, drained by gravity to a 6 by 4 by 6 in. Worthington pump and receiver, which returns the condensation from the coils to the boilers. At two intermediate places in the duct recesses are formed to allow for bends in the main and return pipes for expansion purposes. Globe valves are provided so that any pit can be cut out of service. The pipe used in the construction of the heating system was of wrought iron. This part of the work was installed by the Peters-Eichler Heating Company, of St. Louis, in a very satisfactory manner. As it is almost impossible to heat an engine house entirely, on account of the fact that the doors are very often open a considerable length of time, only sufficient heat is provided to properly thaw out engines as they come in from a trip during the winter. For this reason only 10 000 sq. ft. of radiation was provided. So far, this has been ample for all needs, and has kept the whole house reasonably warm.

One of the essential features of a roundhouse is the wash-out system, which should include a scheme for changing the water in the boilers of the engines when necessary. An elaborate plan for this purpose was decided upon, with the expectation that, with such a system in operation, the boiler repairs



Overhead Pipes for Hot Water Blow-Off, Wash-Out and Filling.



Plant for Washing and Filling Boilers with Hot Water; Wabash Terminal at Decatur.

would be considerably reduced. From results obtained so far a great saving is being accomplished, due to the large reduction in boiler repairs and to the diminished time required for washing out engines, thus greatly increasing their earning power; so the expense in installing this plant has been justified. The pipe lines in the house for this system are attached to the columns close to the roof near the middle of the house. They consist of four different lines: one for washing out the boilers, which extends over 15 stalls; one for refilling the boilers, extending entirely around the house; and two lines for blow-off purposes, one for connecting to the water leg of the engine, covering 15 stalls, and the other to connect to steam dome of the engines, extending completely around the house. The line that connects with the steam dome of the engines leads to a superheater, while the blow-off line from the water leg is connected with two tanks placed one above the other, the steam entering the upper tank, and the water and impurities falling by gravity to the lower tank. In the lower tank is placed a filter which filters out the impurities in order to utilize the purified water for refilling purposes. Pumps operated by electricity are connected with the refilling and washout lines. Cold water is admitted to the system of tanks when required from the Decatur city water supply. In connection with this system there is a temperature-controlling device, which is intended to mix the cold and hot waters to any desired temperature before they are circulated through the house. The heater and the different tanks, with the pumps and temperature controller, are situated in a part of the building which is utilized for the machine shop. With this system an engine can enter the house and have water in its boilers removed and fresh water of practically the same temperature returned to it, and be under steam and ready for the road within two hours' time. If it is necessary to clean out a boiler, the engine is brought on one of the 15 stalls provided for this purpose, the steam and water drawn off, and the boiler thoroughly washed with water of a high temperature. The temperature of the water used is usually about that of the boiler itself, so that the tubes and plates will not be cooled too quickly. There are, on an average, 18 engines per day blown off and refilled or washed out by this plant. The washout system was installed by the motive power department of the Wabash Railroad, the preliminary plans being furnished by Mr. Frederic A. Gale. Patent rights of this system are controlled by the National Boiler Washing

Company. The plant as finally constructed was not built in accordance with the original plans, but was somewhat modified.

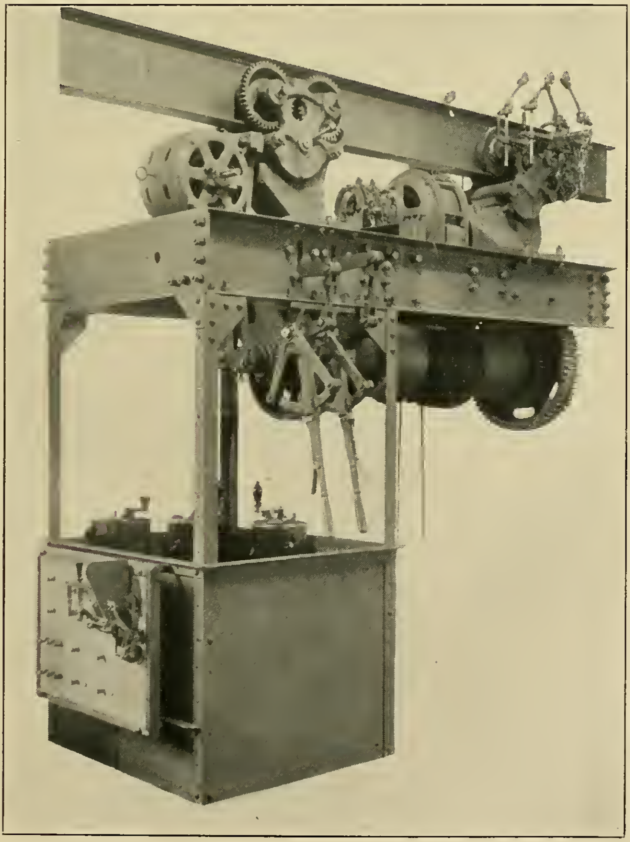
The turntable foundations are supported by piling and are of concrete. The center or pivot foundation is reinforced with rods just above the head of the piles. The circle rail is spiked to short ties laid without any fastenings on the circle wall. The pit is paved with concrete in a manner similar to that in the house and is drained by a 4-in. tile into the catch basin previously mentioned.

The turntable is of the deck type, 75 ft. long, with a live load capacity of 215 tons, and is turned by means of a tractor wheel running on the circle rail and operated by electricity. The steel work of the turntable was built by the American Bridge Company, and installed by employees of the Wabash Railroad Company.

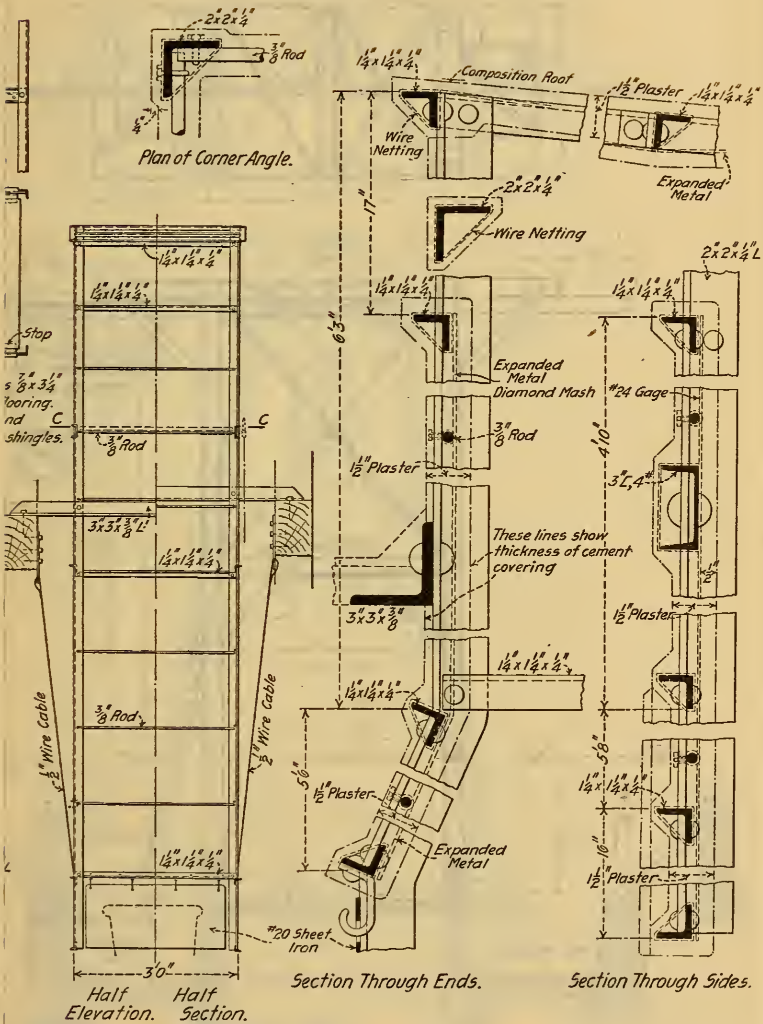
As the cost of labor for handling cinders had been very large formerly, amounting to $600 per month, it was decided to build an ash-handling system that would reduce this cost to a minimum. The structure was planned to have sufficient capacity to hold at least all the ashes deposited by the engines during twenty-four hours, and was provided with machinery with which to load the ashes economically. Concrete cinder pits were constructed in duplicate, 160 ft. in length, in order to permit three engines to be on each pit at a time. The cinders from the engines fall by gravity down an incline into a concrete pit filled with water. Cinder pits are usually hard to maintain on account of the hot cinders collecting in spots and destroying anything in close proximity to them. For this reason, the sloping sides of the pits on which the cinders drop are paved with brick. Columns supporting the track beams and rails are of cast iron of 1-in. metal filled with concrete.

In order to handle the cinders cheaply and quickly, a gantry crane is provided to run on rails between the duplicate pits, on which is hung a telpher hoist, capable of raising a 4-ton weight. This raises and lowers and operates a clam-shell bucket for picking up the cinders and depositing them in cars. A cage for the operator is attached to the telpher, so that he is directly over the bucket at all times. This gantry crane is operated by electricity and moves lengthwise of the pit, while the telpher hoist moves crosswise of the pit. This scheme has worked admirably, and while, as stated above, it cost $600 per month formerly for labor to load the cinders, with this device it practically costs nothing, for the reason that this work is done

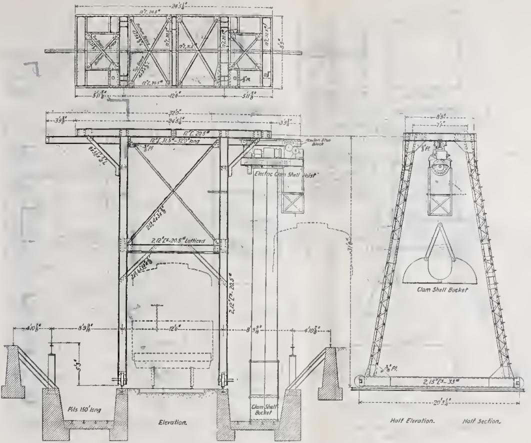
Ash Pit and Gantry Hoist.



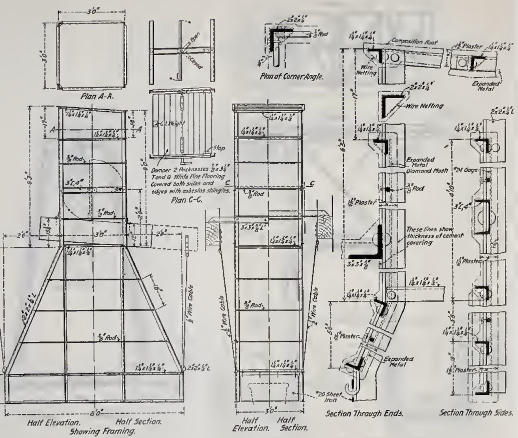
Electric Hoist for Ash Handling Gantry.



OR WABASH ROUNDHOUSE. (See p. 286.)



ELECTRIC GANTRY CRANE FOR HANDLING CINDERS; WABASH TERMINAL AT DECATUR.



STEEL SMOKEJACK FOR WABASH ROUNDHOUSE. (See p. 286.)

by any hostler who may be idle at the time. A certain number of hostlers have to be employed to take care of the engines during rush hours, so that any spare time they have is utilized in operating this machine. There are 70 yds. of cinders removed daily from the cinder pits.

Jas. Stewart & Company, of St. Louis, were the contractors for the house and cinder pits.

The steel work for the gantry crane was constructed by the Decatur Bridge and Iron Company.

The telpher hoist and machinery for the gantry crane, and the telpher hoist for the roundhouse, were constructed by the Case Manufacturing Company, of Columbus, Ohio.

The cost of the above improvements is given below in detail; but, as will be noticed, it does not include the value of the old buildings utilized nor the value of the old machinery and cost of labor for installing it in the machine shop.

Engine house and turntable foundations	$60 000	
Roofing	2 000	
Heating system with pump well, etc	6 220	
Smoke jacks	2 100	
Door anchors	100	
Drainage and sewerage	1 950	
Wiring and lights	1 000	
Grading	600	
Engineering in field	1 000	
Track inside of engine house (value)	1 675	
Telpher hoist	1 000	
Washout system and motors	6 900	
		$84 545
Track between turntable and engine house and labor laying (value)		1 955
Turntable pit and foundation	$3 360	
Turntable	2 430	
Circle rail and track on turntable (value)	685	
Machinery for operating turntable	1 075	
		7 550
Cinder pit	$6 875	
Gantry crane	835	
Machinery for gantry crane	2 950	
Clam-shell bucket (value)	600	
		11 260
Coaling station		8 775
Sand house and machinery (value)		2 000
50 000-gal. water tank and fixtures (value)		1 100
Three water cranes with water pipes and fixtures, etc. (value)		1 000
		$118 185

NOTE. — Items with the word "value" written after them indicate that the material or structure had been formerly used with the old facilities. The amount given is the cost if new.

[NOTE.— Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by March 1, 1909, for publication in a subsequent number of the JOURNAL.]

THE USE OF ASPHALTUM.

By Harry Larkin, Member of the Technical Society of the Pacific Coast.

[Read before the Society, August 28, 1908.]

The paper relates to the various uses of a substance which has been at the service of mankind from the earliest history, in fact, before the date of authentic record. We find evidence of its use for cementing the bricks in building the great temples of the Sun-god and the Moon-god and in other stupendous structures that in ages long ago stood where Babylon with its architectural grandeur housed the rulers of a world, recorded in the most ancient of histories.

The Assyrians used asphaltum for waterproofing the immense irrigation canals built four thousand years ago, and their sources of supply, the fountains of Is, on a tributary of the Euphrates, still yield forth.

The Bible tells us that our forefather, Noah, used this material for rendering the Ark watertight, and that Moses' cradle in the bullrushes was bound together with " pitch."

With such a venerable history as this, it is a strange fact that an intelligent use of asphaltum to-day is an exception both in architecture and engineering. In most cases the advent on a job of a kettle accompanied by barrels of asphaltum, buckets, mops, felt, gravel, etc., etc., is looked upon with contempt—a disagreeable detail that it is hoped will soon disappear. The nature of the work prevents the mechanics looking like the " élite," but, nevertheless, it takes years of practice and experience to develop a thoroughly competent workman in the handling of asphaltum in any of its branches. To the passerby, the humble workman with sooty face and dirty clothing who tends the kettle is a common laborer. The truth of the matter is, however, that an incompetent kettleman may render the work performed very short-lived, whether it be roofing, paving or waterproofing, by overheating the asphaltum. *Here lies the keynote of all asphaltum work.* Nothing will kill the binding properties of asphaltum so quickly as overheating. In laying a felt and gravel roof, the topcoating will be shortlived, the gravel will not be properly imbedded and the roof will soon need recoat-

ing. In a paving job, if either the asphaltum or grit be overheated, the pavement will have no consistency and it will soon crack and go to pieces. In waterproofing work, the surface will be black and the contractor will probably get his money before any evidence of his imperfect work is discovered. On a roof, the greatest care and judgment must be used in laying felt to see that it is properly stretched, laid smoothly and that no wrinkles appear. The spreading of gravel is an art that few can learn; it takes judgment, quick action and a steady hand to get the gravel into the asphaltum before it chills and still leave the finished surface even. In the usual specification not enough stress is laid on the quality of the asphaltum used or on the workmanship. A certain number of plies of a specified weight of felt are called for, to be laid in compliance with the local building ordinances. This may comply with the law, but it does not guarantee a good roof. The same specification will probably call very particularly for a certain brand of cement in the item of the concrete, which is to be used in certain quantities, together with clean crushed rock and gravel. No roof should have less than 100 lb. of asphaltum to the square if a reasonably good job is expected. The asphaltum is the life of the roof, particularly in the topcoating. The gravel should be applied liberally, so that the asphaltum is completely buried and protected from the sun. If there be a little loose gravel on the roof, do not fear it; it will mean so many years more service, for that is what it is put there for, — to protect the asphaltum and felt underneath from oxidizing.

Then, again, asphaltum has been cursed by enthusiasts with ideas; well-meaning men who have done a little laboratory work have produced a sample and gone forth to organize a corporation to spring on the unsuspecting public a production thoroughly impractical in actual use. I have in mind such a corporation that was formed here some eighteen years ago for treating wood piles after a particular manner to prevent their being eaten by teredo and limnoria. These men sent out about a shipload of Val de Travers and Neufchatel asphalts (as good asphalts as have ever been on the market), but when it came to actual usage and wear their ideas proved a failure and the asphaltum lay for years in a warehouse on Battery Street. An honored ex-president of this Society, Mr. George Percy, was one of the few who recognized the superiority of this particular material, and I remember it well that he was ever faithful in specifying its use, to see to it that it was used in preference to all other kinds. In after years this asphaltum was reshipped to the Atlantic coast, the stock-

holders of the corporation having paid the bill for their experience.

In later years a certain contractor of San Francisco thought he could lay street pavements of redwood blocks dipped and coated with asphaltum. You probably remember his work on several of the wharves along the city front, and on Market Street in front of the Phelan Building. Wood block pavements had been laid in San Francisco twenty years before and were subjected to the hardest kind of wear in the steel warehouse of Dunham, Carrigan & Hayden Co., and the Haslett Warehouse at the time the contractor referred to put down his pavement on Market Street; this gentleman's knowledge of asphaltum was limited and as a result all of his pavements were a failure.

The old Boston Mastic Roofs, laid by Mr. Perine some forty years ago, were good serviceable roofs, but their success brought cheap imitations and the city was flooded with roofers who put down a ply of burlap, coated it with coal tar and gravel, collected their bill and flew. The result was that the mention of felt and gravel roofing to a prospective builder for twenty years after that was like a red rag to a bull. At the present time asphalt, felt and gravel roofing is almost universally used in this city, but I fear that some of the work done hurriedly after the recent disaster may have a tendency to shake some owners' faith in human honesty.

On the Pacific coast at present all of the asphaltum in use is derived from the refining of natural mineral oils, the deposits of natural rock asphalt having been exhausted. The process followed in its production is to place the natural oil in a still and take from it the volatile parts, such as benzine, distillate, lubricating oils, etc., the heavier carbons remaining, constituting the commercial asphaltum of to-day. The nature of the asphaltum obtained depends upon the density of the original oil, the care taken in not overheating the still and the length of time required in treating the oil. The hardness of the asphaltum depends upon the length of time it remains in the still — the longer it is treated the harder it gets. I consider that the only proper test of asphaltum is in the kettle, as an asphaltum taken from a high gravity oil may be treated in the still so as to come up to a specified number of points penetration according to the tests of our Board of Public Works and still be unfit for use either for making mastic, grouting basalt blocks or any purpose other than making paint or coating building papers.

Great improvement has been made in the production of

asphaltum in this manner during the past ten years; in fact to-day there are oil asphaltums in the market that very nearly approach the fine cementing qualities of the old rock asphalt. These are derived from low-gravity oils by refinery, where care is taken to produce a superior article. All asphaltums are black, but they are not all good. I am not from Missouri, but I must be shown more than a sample in a little tin can to convince me that the asphaltum I buy is suited to my purpose. There may be some means of telling the binding qualities of asphaltum in the laboratory, but experience teaches me that the most satisfactory means is to use a few barrels on the work and an experienced eye will know whether the material will do the work expected of it.

Asphaltum is a cement in a waxy form. It is nothing else. Its natural tendency is to contract, so that due allowance must be made where it is used either for roofing, paving, insulation or waterproofing. In roofing or waterproofing the object of using saturated felt is merely as a medium to hold the asphaltum together, to allow for expansions, contractions and settlings. In paving the asphaltum is simply a binder for the grit that takes the wear. The tendency to shrink will show itself in a pavement unless it is rolled out and worked by constant use. No better illustration can be shown than the asphalt mastic pavement originally laid in the quadrangle at the Stanford University by the old firm of Coil, Barton & Cowles, predecessors of the Alcatraz Asphalt Company. The pavement was laid as well and of as good material as money could buy, but a student's crossing of the "quad" occasionally was all the use it was put to. The pavement cracked and its surface looked like a map in a geographical atlas in a few years; it was eventually taken up entirely. If the "quad" had been open for driving, the pavement, in its greater part, would probably be good to-day, but lack of use wore it out. Like Portland cement, asphaltum in its pure state is of little use; it must be used in conjunction with felt, grit, gravel and a little common sense, to fill requirements, and it will, when properly and intelligently mixed, fill them well.

In building construction asphaltum is largely used in laying roofs. The methods followed are to lay from four to eight thicknesses of saturated felt over the roof surface, each ply being cemented to the preceding layer with a heavy coating of asphaltum. All felt is turned up at the firewalls and curbs at least 4 in. at the highest points of the roof, and not less than 12 in. high as the outlets are approached, in order to avoid overflows should the outlets become clogged. All such flashings should be

reinforced with an additional layer of felt (preferably flax felt) mopped solidly, running parallel to the wall, and counter-flashed with galvanized iron, or copper wedged, and cemented in place. The entire surface should then be floated with a heavy, flowing coat of asphaltum, in which, while hot, clean, dry, uniformly screened gravel should be imbedded sufficient in quantity to cover the surface thoroughly.

The character of the roof depends upon the style of the building. If a wooden sheathing is used as a foundation, I would advise that the first layer, next to the roof boards, be of unsaturated felt, serving as a dry sheet. There are two reasons for this: First, It is important in the life of the roof that it be free from the building so as to allow for shrinkages of lumber, settling, vibration, etc.; and second, an unsaturated dry sheet will prevent any excess of asphaltum dripping through the cracks, which dripping, however small the quantity, causes great annoyance in a loft building. In the case of concrete or tile construction, I would advise the use of saturated felt entirely, but I would lay the first sheet without mopping to the concrete or tile surface.

Some architects specify a metal standing flashing on felt roofs, but experience has taught me that this is a great mistake. In putting in such flashing it is necessary to nail through the metal and felt in order to hold it in place. Expansion and contraction soon loosen the nails, and if the flashing be in a position so that the water may flow on it, an opening will be found in the course of time to cause a leak. I never, under any circumstances, put a nail through a felt roof if it can be avoided, and if compelled to do so I make sure that it is well covered with felt. A reinforcement of flax felt, mopped on solidly, is more satisfactory in every way.

When an unusually fine job is wanted, a second coating of asphaltum and gravel is often put over the roof as heretofore specified; or, as in the case of light-well roofs, an improved appearance and a clean surface may be had by putting a cement top finish over the gravel roof; or tile may be set in concrete over it. But in any event, lay the roof first, complete with flashings and counterflashings, and then finish the surface to suit your taste.

Asphalt mastic has been used as a top finish over felt roofs, but this has not been altogether satisfactory on account of the tendency to contract, the mastic cracking in time and permitting water to lodge directly on the felt where this is laid without first

graveling it. Actinolite has given good service as a substitute for mastic where a smooth surface is wanted. Its cost and weight are much less than either tile, cement or asphalt mastic, and this material has the advantage of being adaptable to steeply pitched surfaces as well as flat ones. It is the only material other than tile that gives a thoroughly satisfactory smooth finish to a felt roof. This desire for a smooth surface is solely a matter of appearance, for accumulations of dust and dirt, that do so much harm to a metal roof, have a tendency to preserve an asphalt roof by protecting it from the sun's rays and oxidization. *The life of any roof is in its top finish.* If the roof be a plain felt and gravel roof, a liberal amount of asphaltum and gravel on top is of more importance than the number of plies of felt, or the quantity of asphaltum put between the sheets.

What is known as a felt-and-gravel roof should never be used on a surface of greater pitch than one sixth, or 4 in. to the foot. Where it is necessary to use an asphalt roof on a greater pitch, the gutters may be put in with plies of felt and asphaltum and the steeply pitched surface covered with some of the many ready roofings on the market. There is little choice between the different brands, for they all are laid with joints cemented and nailed to the sheathing. This nailing is what makes them so unsatisfactory; expansion and contraction of the body material in the course of a short time open holes alongside the nails and permit water to enter.

Asphaltum may be used to great advantage in other parts of a building. A recent fire on Market Street, opposite Sansome Street, brings to mind a fad of mine that appears to be in every way reasonable. At the time of the fire (which occurred in the upper story) newspaper reports stated that H. S. Crocker & Co. had a stock of $25 000 of very perishable goods on the ground floor, the loss being $23 000. Now, if in the construction of the building a waterproof course of two-ply felt and asphaltum had been put in the upper floors, the greater part of the damage to the stock below would have been prevented. Such waterproof course would have cost 3 cents per square foot, and besides making the floor watertight, it would have been the finest deadener of sound and barrier against rats that could have been put in.

In certain localities precautions must be taken to keep water out of basements. In these cases the treatment depends upon the character of the building and foundation. In heavy structures it is best to wait until the building is nearly completed, and when it has settled to its final resting place then pump out the

basement and over a thin foundation layer of concrete mop solidly three plies of good saturated felt, running the felt up the walls and piers a little higher than the natural level of the water, and cover this felt with from 8 to 12 in. of good cement and top-finish to serve as a floor. This cement must be built up around the piers and along the walls to support the waterproof course in place. On brick or concrete foundation walls a continuous course of asphaltum, applied to the outer side of the wall, will prevent entrance of ordinary dampness, but in cases where a great amount of water is present, I would recommend mopping on two plies of felt and filling in the earth at once as a support. The use of felt and asphaltum in waterproofing work is very general throughout the East, and some of the structures so treated are very extensive, such as the subways recently completed in New York. In letting contracts for such work, and in fact all asphaltum work, the integrity of the contractor is of greater importance than the cost, for it is seldom that a waterproofing job is so situated that it can be reached after the work is completed, and if there be a single defect, the full amount paid is loss.

The civil engineer often has use for asphaltum in lining reservoirs and flumes, and in waterproofing retaining walls and cisterns. The same simple rules of handling as already mentioned will apply. We all learn from noting failures, and I cannot help but mention here two particular instances of poor judgment or ignorance of the material that have come to my mind. When the water-works were built at Portland, Ore., some fifteen years ago, the three higher reservoirs were lined with concrete, and this lining was in turn coated with straight asphaltum. The coating was done during the winter season by unskilled workmen and, as a consequesence, was in patches and nowhere continuous. As the work was not satisfactory to Colonel Smith, the engineer, the entire surfaces were gone over with paving irons, and, in the course of time, the asphaltum was ironed together, but the life was burned out of it and an immense expense was incurred without accomplishing anything. If skilled workmen had been employed, the first application would have cost less and the job would have been acceptable.

The other case was a reservoir of the Contra Costa Water Company, on the outskirts of Berkeley. The reservoir leaked and a specification was prepared calling for the surface to be coated with asphaltum in which burlap was imbedded. This burlap was in turn given a heavy coating of asphaltum, probably

two coats. Where the mistake was made was in the burlap. Asphaltum will not penetrate anything while in its natural state. No force can be applied that will make it enter the pores of burlap, canvas, concrete, brick, stone or wood. As soon as it chills it sets, and in the case of the burlap, a simple surface coating was made through which the fibers of the burlap extended, to rot and draw moisture into the body material, to cause it to decay in turn. If a material like flax felt had been used, having for its foundation practically the same stock as burlap, but which is saturated with a preserving substance that harmonizes with asphaltum, the result would have been a satisfactory job instead of the failure, without question.

All of the roofing felts on the market are made of wool or flax, saturated with a preserving material that will harmonize with the asphaltum. The felts simply constitute a medium for holding the asphaltum in place, as before stated. The saturated wool roofing felts are compact, and although they absorb little of the asphaltum used in laying them, they hold it in repeated layers to constitute the body material of the roof or other structure to which they are applied. The flax felt is porous and of strong texture and absorbs the asphaltum, holding it within its fibers. An unsaturated burlap or canvas cannot be made to hold the asphaltum unless it be first run through a bath of flux, liquid asphalt or tar.

Herein lies a field for an energetic manufacturer: to produce a mixture of asphaltum and some material of the same specific gravity of the character of mica or asbestos, or something indestructible through decay, but which has a fiber to it that will hold the asphaltum together, or, in other words, that the asphaltum will hold together. Such a compound would be invaluable for coating reservoirs, pipe conduit, insulation, etc., if it be of a consistency easily handled. A refinery in Bakersfield is placing on the market a combination which it calls mastic, consisting of oil. asphaltum and lime from the beet sugar refineries. The lime tends to toughen the asphaltum in the same manner as sand, but it lacks the fiber to bind it together. The firm has the idea, but as yet it has only succeeded in adulterating the asphaltum without any material gain.

Asphaltum has been used in various characters of paving with varied success. The bituminous rock which has been so generally used in California is a natural mixture of sand and asphaltum found in large deposits along the coast. For sidewalks or streets having moderate wear it makes a very satisfactory

and cheap surface covering. Wherein it is weak is in the loam and vegetable matter in the mixture, and in the sand itself not being sharp; besides, the method of disintegration with steam leaves the finished pavement porous so that when the cold and damp weather comes on it cuts out into ruts. The character of "poultice pavement" more recently used in San Francisco has been a mechanical mixture of crushed rock for a binder, with a similar mixture of asphaltum and sand for the wearing surface. Provided the sand be clean and sharp, these pavements will give far better service than bituminous rock. Both the asphalt mastic and bituminous rock pavements cost little to keep in repair and have the advantage of being the most sanitary covering that can be placed on a public street. For streets having heavy traffic or even a slight grade, there is nothing better for wearing surface than basalt blocks grouted with clean warm gravel and asphaltum. It was a great blessing to San Francisco that Third Street, from the freight depots to the business centers, was so paved at the time of our recent disaster, for it gave us a passable thoroughfare over which to truck our supplies for building and stocking up the mercantile community again. After thousands of tons of all kinds of material have been hauled over it, the street is in good condition to-day, barring a few minor faults caused by excavations necessary for connecting new buildings. I doubt whether the city has spent a cent on this thoroughfare from Townsend Street to Mission Street since this pavement was laid some five years ago.

Pavements consisting of wooden blocks laid on vertical grain, dipped and grouted with asphaltum and warm gravel, make an excellent wearing surface for driveways inside of buildings. They are comparatively noiseless and furnish a good foothold for horses. In warehouses nothing will give better satisfaction. I consider fir blocks, cut at least 4 in. long, out of stuff not over 4 by 8, will make the best pavement when the blocks are laid to break joints and are well grouted with gravel and asphaltum. In case of very heavy teaming, blocks 6 in. deep would be better, but I would not recommend larger sizes than 4 by 8, as before mentioned. Creosoting the blocks does more harm than good. If the blocks are well dipped and grouted, they will never fail through decay. In this climate a wooden block pavement will never give satisfactory service out of doors. It is for this reason that I confine my recommendation of it to the use in warehouses and driveways under cover.

The foundation is all important whatever the character

of the pavement. Concrete has no superior. Our practice of ripping up a pavement for sewer, water and gas connections, and for laying conduits, has been the cause of numerous faults in our streets, but if the repairs were conscientiously made, the patching would never be evident whatever be the character of pavement. That is one peculiarity of asphaltum — it will heal over an injury in a roof or pavement, when the patch is properly applied, at a small cost, and in the end will be better than new. It has always been a source of pride and satisfaction to the asphaltum man to know that when the good metal, slate or tile roofs leak, or the concrete or brick walls sweat, he will be sought in the end to apply his asphaltum in some form or another to remedy the defect. The use of a few dollars' worth of asphaltum in building the foundation walls and basement floors in localities like the Western Addition, north of Washington Street, or over the entire area of Berkeley, would save our clients endless expense after the residence is occupied. The two localities are peculiarly subject to underground dampness, and there is hardly a residence in either locality that is not troubled in winter. This is a hard matter to correct after the building is up, but an inexpensive one to prevent in first construction. Tile roofs please the artistic eye and appeal to our loyalty to peculiarly Californian mission architecture; but a course of felt and asphaltum is advisable under the tile, to keep the rain out in rainy weather when the advantages of the roof are most needed. Our changing from an iron to a steel age has rendered metal roofs of short service; the steel oxidizes so rapidly that it is only a question of a short time when the owner will send for the asphalt man to put a covering over his head that will let him rest securely and keep him dry.

The statements I have made favoring the use of asphaltum are with the presumption that intelligence be used in its application. Asphaltum is most excellent for some uses, but like wood, steel, stone or brick, it has its field and cannot be successfully used without judgment.

[NOTE. Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by March 1, 1909, for publication in a subsequent number of the JOURNAL.]

DISCUSSION OF PAPER BY C. E. GRUNSKY, "THE WATER SUPPLY OF SAN FRANCISCO, CAL."

(Vol. XLI, Page 73, September, 1908.)

F. P. Stearns (*by letter*). — Two reasons have induced the writer to discuss this paper. First, the serious criticism that for other than engineering reasons he has expressed views while acting in a professional capacity in San Francisco which differ from views which he has expressed while acting in a similar capacity in Los Angeles; and second, because of his interest in the engineering questions involved in the water supply of San Francisco.

The author of the paper objects strongly to the view of the writer that the water diverted from the Tuolumne River should be conveyed in a covered conduit instead of an open canal along a steep hillside, and he quotes from the testimony of the writer in 1905 relating to the open canal section of the Tuolumne project as follows:

"In an unlined open canal on a steep hillside, as in this case, water would deteriorate in quality both by its exposure to the sun in the shallow canal and by opportunity afforded for the pollution of the water; some would be lost by filtration, and such a canal would be more liable to accidents and interruption than a tunnel. It would seem to me advisable, in view of the very great length and cost of the work, that this portion should be built wholly in tunnel, fully lined, so that the works would be less liable to interruption and to the liability to pollution and deterioration of the water which I have spoken of."

He then quotes from the report to the city of Los Angeles a paragraph which, to the casual reader, might sustain his contention that different views were expressed in the two instances without an adequate engineering reason.

In the testimony quoted there are four principal objections to the plan — two relating to the efficiency of the plan for an unlined open canal on a steep hillside: *First*, that some water would be lost by filtration; *second*, that such a canal would be more liable to accidents and interruption than a tunnel, which then seemed the most advisable way of constructing a covered channel on such a steep hillside; and the *third* and *fourth*, relating to the quality of the water, that it would deteriorate by its exposure to the sun in the shallow canal and that there would be an opportunity afforded for the pollution of the water.

The writer still holds these views, and held them at the time he joined in the report to the city of Los Angeles, and that report is not in any way inconsistent with the views expressed in the testimony above quoted.

In regard to the loss of water: The only portion of the Los Angeles aqueduct which is to be left unlined is, as stated in the report, "for the first twenty miles through the Owens valley" where "the canal will be sufficiently below the normal water plane in clayey soil of close texture to require no lining." Everywhere except in these wet, flat lands the canal is to be lined with masonry. It is also to be noted that this portion of the Los Angeles aqueduct is a part of a feeder to the main storage reservoir and is a large canal having a capacity for conveying 700 cubic feet of water per second.

On steep side hills where there would not only be the loss of water above referred to, but danger of interruption and accident, the Los Angeles canal is not only to be lined, but also covered. This is shown by a quotation from the Los Angeles report relating to a section along the mountain side where the conditions are much like those along the steep side hill where the author of the paper proposes the unlined open canal:

"From Little Lake to Indian Wells, a distance by the conduit line of 24.5 miles, is a section of more difficulties than the ordinary, as the line must be supported on the mountain sides at an elevation of 200 to 500 feet above the valley, along which the highway follows at the base of the Sierra. Here a succession of tunnels, siphon pipes and bench conduit, excavated much of the way in solid rock, and covered from the outset with reinforced concrete, are required."

The question as to whether or not an open canal should be used on the portions of the Los Angeles aqueduct to which such construction is adapted involves entirely different considerations from the use of an unlined open canal as a part of the Tuolumne project, as originally recommended by the author of the paper. In his plan as then laid down, and as reiterated in the paper under discussion, he lays great stress upon the quality of the water, evidently having in mind the quality of the water as it flows in the mountain streams; but the quality of the water supplied to a municipality may be greatly changed in character by storage in reservoirs and by exposure in a shallow, open canal. It is not a part of the San Francisco plan to purify the water by filtration through sand, but to deliver it substantially as it comes from the pipes, with only a few days' storage in reservoirs en route and in the city.

In the Los Angeles supply, on the other hand, although the water comes from the Sierra Nevada Mountains with a purity probably closely equivalent to that from the upper reaches of the Tuolumne River, it is stated in the portion of the report which the author has quoted in his paper that it was recognized that when it reached the Owens River it was somewhat changed in character, so that it had a slight turbidity and stain. Neither this condition nor the fact that there is a small population in the Owens Valley, nor the further fact that the open channel does not furnish a complete protection against the deterioration and pollution of the water even in a desert region where there is practically no rain and no population, is of great importance in view of the additional fact that the water after leaving the Owens River will pass through a storage reservoir of fully two thirds the capacity of the proposed Hetch Hetchy Reservoir on the Tuolumne River, 200 miles from San Francisco, then be stored again in great reservoirs in the San Fernando Valley near Los Angeles, and then be thoroughly filtered, probably through the natural gravel-bed filters above the heads of the existing aqueducts, before it would reach the consumers in the city of Los Angeles.

It is a matter upon which there is a general agreement among sanitary engineers that even a somewhat polluted water can be made safe for drinking either by long storage or by adequate filtration, and with the double safeguard of very ample storage and adequate filtration, the water delivered to the city of Los Angeles should be more wholesome and palatable than that taken directly from a mountain stream.

Conversely, the most dangerous water supply is one taken from polluted streams without storage or filtration. Practically all if not all of the epidemics of typhoid fever which have been definitely traced to water supply have been of water either taken directly from flowing streams or which have been held but a short time in storage reservoirs before being delivered to the consumer. That sparsity of population is not a complete safeguard is shown by the epidemic at Plymouth, Penn., where the contamination of a stream resulting in an epidemic of typhoid fever was traced to a single farmhouse.

The plan under consideration for the water supply of San Francisco provides for taking water into an open canal from the Tuolumne River, 16 miles below the proposed Hetch Hetchy Reservoir, and about the same distance below Lake Eleanor on Eleanor Creek. In addition to the watershed tributary to the

portions of these two streams below the reservoirs, which will be delivered directly into the canal without storage, there is also an important stream known as Cherry Creek, the head waters of which are 37 miles, measured along the stream, above the point of diversion. During all seasons, therefore, when the streams are contributing water, a considerable proportion of the water diverted to San Francisco will be that taken without storage directly from a stream, and containing the suspended matter which is always found to a greater or less extent in the water of streams.

The open, unlined canal into which the water of the river would be diverted has a length of about 28 miles, and the greater part of it is located at an elevation of about 1 900 feet above the sea, in a territory in which there is a small population and where, according to statements made to the writer, the country is used for grazing. The rainfall at this elevation is about 33 inches per year, and most of this is concentrated in the half of the year known as the rainy season; during the other half of the year the sun shines almost continuously.

The proposed depth of water in the open canal is said to be 5 feet, and this presumably is the depth corresponding to a capacity of 100 000 000 gallons per day, as that figure is mentioned in the official report on a supply from the Tuolumne River, made by the author in 1901. The present consumption of water in San Francisco is about one third of this quantity, and in the earlier years the depth of water would be much smaller, probably not more than 2 or 3 feet.

The writer has observed many irrigation canals in Southern California, and even where lined with concrete there is a prolific growth of vegetation attached to the sides, and he sees no reason to doubt that vegetation would grow and decay in the unlined canal under consideration. In addition to this, he does not believe that it is feasible to intercept all of the rain water falling on the steep hillside above the canal at all times by a system of small ditches. Under these circumstances it seems inevitable that the water would deteriorate in quality in passing through such a canal.

The author of the paper, notwithstanding his claims as to the high degree of purity of the water from the Tuolumne River, evidently has in mind that as delivered in San Francisco it would not be above suspicion, because, after stating in his paper the various small reservoirs through which it would flow on its way to the city, he suggests that it "can be made to flow through the

proposed Belmont Reservoir, whose capacity is estimated at 3 000 000 000 gallons, although this would involve some additional pumping."

As the flowline of the Belmont Reservoir would be about 160 feet below the hydraulic grade line of the pipes leading to the city, all of the water discharged into this reservoir would require pumping, and, in order to use the pipes leading to the city to their full capacity, pumping against a head of about 160 feet would be required.

It is obvious that to carry out this suggestion for producing a more wholesome water would involve a very large annual cost for pumping.

Another criticism made by the author of the testimony of the experts in the San Francisco case is that they have stated that the water of the Tuolumne River would be unfavorably affected by storage in the Hetch Hetchy Reservoir, which, he says, is located in the mountains at an altitude of 3 600 feet.

Large reservoirs have a beneficial effect upon impure, turbid or discolored water by destroying disease germs, causing turbid waters to settle and become clear, and causing discolored waters to bleach, and the Hetch Hetchy Reservoir might improve the water in these directions; but it is also true that algæ and other minute organisms which are found only in very limited numbers in streams occur in much larger numbers in reservoirs, even though they are fed by the purest spring water or the purest water from mountain streams, and such organisms at times give the water an appreciable taste and odor.

This testimony as to the effect of storing water in the Hetch Hetchy Reservoir, if given by the two experts who were afterward engaged on the Los Angeles supply, is not inconsistent with their views as expressed in the Los Angeles report. If the author had continued his quotation from that report he would have included the following paragraph which relates to the Haiwee Reservoir, located at an altitude of 3 760 feet:

"Although the storage of water in a reservoir has a favorable effect in the directions indicated, it sometimes promotes the growth of water plants or algæ, which make the water less palatable and attractive; these growths are liable to occur with any water, and have very little, if any, sanitary significance. It is not feasible to prevent them, but it is feasible to remove their effects by aëration and filtration."

It should not be inferred from the remarks which the writer has made regarding the quality of the Tuolumne River water

after it has been stored and run through open canals that he believes the water delivered in San Francisco by the works proposed by the author of the paper would not be a first-class water judged by the standard of the water supply of cities throughout the United States. In the present instance, however, a comparison is being made between the relative quality of two supplies, one of which is comparatively near San Francisco and the other at a great distance, and both are hygienically of a very high class, so that it needs a consideration of small differences to determine which is the better water.

The author, still referring to the Los Angeles project, states:

"The consulting engineers say of this project: 'We find the project admirable in conception and outline, and full of promise for the continued prosperity of the city of Los Angeles.'"

He then asks this question:

"Compared with Owens River the Tuolumne River is a far more desirable source of supply. Are not, therefore, the same words of praise applicable to the Tuolumne River project in so far as the source of supply and the compared features of the project are concerned?"

This question may be answered to a considerable extent by placing some of the main features of the two projects in parallel columns. The estimates of cost and capacity of the Tuolumne River plan are those given by the author of the paper. It should also be noted that the estimates for the Owens River works are for the portion of the system 226 miles long, extending from the source to the San Fernando Valley, from which the supply of Los Angeles is now taken. A small additional expenditure will be required to convey a part of the water from the end of the aqueduct to filter beds.

	Tuolumne River.	Owens River.
Estimated cost of works, exclusive of distributing system	\$30 724 000	\$24 486 000
Daily capacity (gallons)	60 000 000	258 000 000
Cost of works per million gallons daily capacity	512 067	94 907
Total length of aqueduct (miles) ..	182	226
Riveted pipe (percentage of whole length)	76	4.8
Method of supply	Constant pumping against head of 625 ft. and pumping in emergencies from Belmont Reservoir.	All gravity.

The Owens River supply for the city of Los Angeles requires a very large expenditure of money in comparison with the size of the city to be supplied, but it is essential that a further water supply should be obtained for this city, and very desirable that it should be obtained without taking water away from the irrigators in Southern California, thereby decreasing the prosperity of that section of the country. It is also desirable that the additional supply should be made so large that the greater part of the water could be used for irrigation, and thereby indirectly increase the prosperity of the city.

It would not have been good engineering to go to so great an expense to obtain a new water supply for Los Angeles had it been possible to obtain at less cost a liberal supply not already in use for irrigation from a nearer source; but as no such source was available, it was a matter of congratulation that the physical conditions between the distant source and the city were such that a great quantity of water could be obtained by gravity, almost wholly through works of a permanent character, so that the annual cost for maintenance, renewals and repairs would be comparatively small. Also that on the line of the aqueduct, comparatively near to the city of Los Angeles, there is a somewhat abrupt fall where electricity can be developed to the extent of 36 000 electrical horse-power for twenty-four hours of the day every day in the year, equivalent to about 80 000 horse-power if concentrated in the working hours of the working days of the year.

The words of praise applied to the Los Angeles project would not be applicable to the Tuolumne River project for two principal reasons: *First*, because it is feasible to provide an ample supply of pure water for San Francisco from nearer sources, by works which would be much more economical, efficient and reliable. This point will be elaborated subsequently. *Second*, because of the unsatisfactory features of the plan for taking water from the Tuolumne River, many of which are inherent in any plan for taking water from this source; namely, the great cost in proportion to the quantity of water which can be made available; the unreliability of a system of so great length, which is made up to a very large extent of pipes under high pressure; the pumping against the unusual head of 625 feet with electricity generated 60 or more miles away, even though "some steam power is to be held in reserve for use in emergency"; and the absence of any large storage of water near the city for use in emergencies, except that contained in a storage reservoir from

which the water has to be lifted at an emergency pumping station.

Leaving now the criticisms made by the author and the comparisons between the Tuolumne project and that for taking water for Los Angeles from the Owens River, and reverting to the engineering questions involved in the water supply of San Francisco, the question which has always stood out with great prominence in the writer's mind is, Why go the great additional distance to the Sierra Nevada Mountains for a supply when an ample quantity of pure water can be obtained comparatively near at hand at a fraction of the cost and by works which will be thoroughly trustworthy and efficient?

The author at several places in his paper indicates his preference for the plan of future water supply for San Francisco which utilizes the established water works and adds thereto as a first enlargement water from the Tuolumne River to the extent that it could be obtained by laying one pipe 48 inches in diameter which would convey 30 000 000 gallons of water, or, possibly, by laying a larger pipe.

Accepting the plan for one 48-inch pipe, it is feasible to make comparisons of the cost of an additional supply of 30 000 000 gallons of water from the Tuolumne River and from the development of local sources delivered at the point where the proposed pipe line crosses Calaveras Creek, about 55 miles from the proposed receiving reservoir in San Francisco.

The author states in his paper that:

> "It seems reasonable to expect that the Calaveras Reservoir will make available about 25 000 000 gallons per day of the 35 000 000 that should flow through or past the reservoir in Calaveras and Hondo creeks. San Antonio Reservoir may bring within reach 4 000 000 out of an average of about 6 000 000 gallons per day."

He therefore thinks it reasonable to expect that 29 000 000 gallons per day can be obtained by the construction of these two reservoirs, and this is only 1 000 000 gallons less than his estimate of the capacity of one pipe line.

It is to be noted that although the mountain water and that from local sources would be brought to the same point, where the pipe line crosses Calaveras Creek, yet the water pressure in the pipe would be that due to a head of several hundred feet.

The writer does not think this additional pressure in the pipe any especial advantage, and if it were so considered it ought also to be noted that the Calaveras Reservoir, which will furnish

25 000 000 gallons per day out of the total of 29 000 000, is considerably nearer San Francisco, measuring along the proposed Tuolumne pipe line, than the point of crossing above mentioned, and it is at such a height as to give more pressure than is proposed for the Tuolumne pipe line.

The cost of conveying water by gravity from Calaveras Reservoir to the city would be less than that of conveying the Tuolumne water by gravity from the crossing above mentioned.

The total cost of the Tuolumne works down to Calaveras Creek, as estimated by the author of the paper, is substantially $19 600 000 for a system with two 48-inch pipes and pumping and power stations of corresponding capacity. If this estimate is diminished by deducting one half of the estimated cost of pipes, pumping and power stations, and of such other portions of the work as can be built on a smaller scale in the beginning and subsequently added to, amounting in all to $7 300 000, but without cutting down the estimate of the cost of the Hetch Hetchy and other reservoirs and of tunnels and canals, the estimate becomes $12 300 000, or, making some allowance for cutting down the size of permanent works, say, $12 000 000.

On the other hand, the writer has estimates of the cost of building the Calaveras and San Antonio dams, which he believes to be liberal, which amount to a total of $4 600 000.

In the case of the Tuolumne system the construction cost per million gallons of capacity for the water delivered at Calaveras Creek is $400 000, while the cost of substantially the same quantity of water obtained by developing the local sources amounts to $159 000.

The author gives a tentative estimate of the ultimate capacity of the Spring Valley Water Company's sources as developed, amounting to 109 000 000 gallons daily, which is well up toward double the quantity of water which he estimated would be required for the city in the year 1950, and substantially the same as the estimate made by the engineer of the Spring Valley Water Company of the probable consumption in that year. It cannot, therefore, be contended that the development of the nearer sources will not meet all of the requirements for a long time in the future.

He stated in a report quoted in his paper, when comparing the Tuolumne River project with the Spring Valley Water Works system, that the latter "ranks first in reliability of service." There is left, therefore, only the alleged superior quality of the mountain water as a reason for much more than doubling the

cost per million gallons of works for obtaining additional water.

Whatever may be the relative merits of a mountain water as compared with that of the nearer sources, the writer believes that there can be no question that the water from the nearer sources, filtered through adequate sand filters, would be more wholesome and more palatable than the water delivered from the mountain sources by the works proposed by the author. The cost of works for such filtration, added to the cost of developing the nearby sources, would not make the total more than $200 000 per million gallons daily capacity, which is just half the estimated cost per million gallons of water delivered at the same point from the Tuolumne River.

The wide difference in the first cost of the works does not by any means tell the whole story. The supply developed by building dams will flow to the common point at Calaveras Creek by gravity, or, if it were desired to convey it by gravity to San Francisco, $\frac{25}{29}$ of the additional supply could be so conveyed, while all of the water from the Tuolumne River would have to be continuously pumped to the great height of 625 feet. The expense for such pumping would be much greater than for the operation of filters and probably would be as great as for the total cost of water filtration, including fixed charges, which is frequently estimated at $10 per million gallons.

In developing the nearer sources the only works to be maintained above the common point mentioned would be the two reservoirs, and in the other case there are works extending for a distance of more than 127 miles, a part of them in a territory difficult of access. The dams would be permanent structures, while the pipe lines, pumping stations and power plants of the Tuolumne project would involve large future outlays for repairs and renewals.

To conclude the discussion of the relative merits of the Tuolumne project and of a project for developing the existing sources: The author concedes that the latter sources are more reliable and that they can be developed to supply all the water required for the next 40 or more years. It is not thought that he will contest the view that the cost of the construction and maintenance of the two dams referred to, including also the construction, maintenance and operation of works for the thorough filtration of the water through sand, will be very much less than the cost of the construction and maintenance of the Hetch Hetchy dam and the building, maintenance and operation of the

works 127 miles in length required to pump the water and convey it to the common point in the Calaveras valley already mentioned.

There is left only the relative quality of the water. It is the writer's contention that the water derived from the Tuolumne source, taken in part directly from streams and in part from a reservoir, and all conveyed through 28 miles of open, unlined canal, will be little if any better than the water from existing sources, and he believes that, by the filtration of that portion of the water taken from existing sources which is not already filtered, a better water can be supplied to San Francisco than the unfiltered water from the Tuolumne source, and for much less than the cost of obtaining water from that distant source.

While the foregoing pages have been devoted to answering criticisms made by the author and to a discussion of his plan for an additional water supply for San Francisco, the writer recognizes that there are many statements in his valuable paper with which he is in complete accord.

Mr. C. E. Grunsky. — The most important requirement relating to the water supply of a municipality is that the water be of good quality. It must be pure and wholesome. This requirement is not yet fully appreciated by the water consumer. The water supplied to many of the larger American cities is not above suspicion and in too many cases it is known to fall far short of the desired standard. No water is entirely satisfactory unless it can safely be used to quench thirst. The general lack of confidence in the water supplied to the larger cities of the Atlantic slope is evidenced by the extensive use of bottled water which, as it reaches the consumer, is attractive in appearance and which the public, though often without adequate guarantee, accepts as safe.

This requirement was not lost sight of in the design of the proposed water works for San Francisco which, as explained in the paper, had to be presented as a project separate and apart from the established privately owned works. It has been pointed out in the official reports on the Sierra supply, as well as in the paper, that the Tuolumne River project would best be carried out as an addition to the present works instead of as a competitive water supply. This point of view rendered it unnecessary to discuss minutely at this time the merits of the Tuolumne River as an independent source of water. It may be stated, however, that when this water was under study by the writer as city engineer, in 1902 and 1903, the conclusion was reached on the basis of appraisements then made and an allowance for

the cost of utilizing the Calaveras Valley properties that the first cost to the city of acquiring the established works with capacity increased to between 50 000 000 and 60 000 000 gal. per day would be about $37 000 000. The Tuolumne River project, with a daily capacity of 60 000 000 gal., was estimated to cost $39 531 000. A complete distributing system was included in both cases.

Since the paper was presented, the question has been submitted to the voters of San Francisco, whether the first step toward the acquisition of municipally owned water works should be taken. The question passed on by the voters related to the issuance of bonds in the sum of $600 000 for the purchase of lands in the Hetch Hetchy Valley and at Lake Eleanor. The voters, at the election which was held on November 12, 1908, endorsed this proposition by a vote of 6 to 1. Still more recently the Spring Valley Water Company, which, prior to the election, had failed to set a price upon its properties at which they might be acquired by the city, has again been asked if it desires to sell its properties to the city. A letter from a committee of the Board of supervisors of the city and county of San Francisco contains the following: " Reduced to a simple statement, the position of the Board of Supervisors is as follows: To proceed without unnecessary delay to the purchase or construction of a water works to be owned and managed by the municipality. In accordance with the provisions of Ordinance No. 505 (New Series) you were so notified. You were given opportunity to offer your properties for sale to the city if you so desired. On September 15, 1908, the Public Utilities Committee directed your attention to ordinance No. 505 (New Series) affording you another opportunity to negotiate with the city. At this time the Water Rates Committee asks the question: Do you wish to sell the properties of the Spring Valley Water Company now used in supplying water to the city and county of San Francisco to the city and county? "

The question is still pending.

How the Tuolumne River water supply project compares with the established water works was set forth by the writer in a report which he made as city engineer under date of November 24, 1902, which has been referred to by Mr. Stearns. The following is from that report:

" It appears from what has been said on the foregoing pages and the earlier reports herein referred to:

" That the Spring Valley Water Works system, to the extent of its capacity, ranks first in the reliability of service.

"That the Tuolumne River project ranks highest in the quality and quantity of water.

"That in the matter of first cost to the city the advantage should be in favor of the Spring Valley system. (A sale at a fair price is to be assumed.)

"It is to be added that in the matter of operation, it remains uncertain which system, the Tuolumne River project or the Spring Valley Water Works, would have the advantage — the probality being in favor of the newer system."

In comparing the cost of water from the Tuolumne River at Calaveras Creek with the cost of impounding water on this creek and on its tributary, the San Antonio Creek, it should be remembered that all of the water from the Tuolumne River at that point, having been pumped over the summit at Altamont, is under pressure sufficient for its delivery in San Francisco.

The Calaveras Valley water, also, is at a sufficient altitude to flow by gravity to San Francisco, but not the water of San Antonio Creek, which would require pumping. The construction of the dams at Calaveras Valley and on the San Antonio Creek would hold back water that now flows into the Suñol gravel beds. How much their construction would decrease the output of these gravels is somewhat uncertain. It may be 5 000 000 to 10 000 000 gal. per day. The unit cost of the new development should, in other words, be figured on the basis of less water than assumed by Mr. Stearns.

He states in this connection that the cost of pumping Tuolumne River water over the summit at Altamont against a head of 625 ft. would probably be as great as "the total cost of water filtration, including fixed charges, which is frequently estimated at $10 per million gallons." For those who wish to analyze this statement it should be repeated that the pumping at Altamont will be with power generated by the water at Bear Gulch and electrically transmitted. The pumping of the San Antonio Creek water would not be so economical.

It is, however, true, in the light of information now at command, that the first cost of developing some of the additional coast range sources would be less than the cost of bringing in water from the more remote Sierra Nevada. The justification for going further for the water lies in the superior quality of the water to be thus obtained and delivered.

Without entering upon a discussion of the quality of the water which San Francisco has been and is to-day receiving, the exceptional purity of the water from the high mountains of the Sierra Nevada is again emphasized in order that it may

be understood why first cost and reliability of service are minor considerations.

The water as it is liberated from the mountain reservoirs, according to every fact now known, will be of prime quality. In this respect, as stated in the paper, the Tuolumne River as a source of supply will differ from Owens River, concerning the water from which the engineers say "that it has a slight turbidity and stain, owing to the drainage from the marshes in Long Valley, and to other return water from the canals and irrigated lands" (of Owens valley). The Owens River water, in other words, is to be improved in transmission to the place of use, while the Tuolumne River water starts pure* and needs no treatment for improvement unless first allowed to deteriorate in transit. The Sierra Nevada Mountains are full of lakes with water appearing crystal clear. Those of the glaciated region under consideration appear exceptionally free from algæ and other plant life. In the water of Lake Tahoe, as stated in the paper, no bacteria were found in three out of four water samples plated on the ground; only one per cubic centimeter in the fourth sample taken nearer shore and only sixty in a sample taken at another time, but rejected for cause. The analysis of Lake Eleanor water is given in the paper. It is not apparent why it should be assumed that water will deteriorate in a Hetch Hetchy reservoir or that such a reservoir will behave like some reservoirs at lower altitudes in other parts of the country instead of like the water bodies already existing in its vicinity. Neither is there any need of discussing the effect that a reservoir of similar capacity would have on an impure turbid water. The water reaching the Hetch Hetchy Valley is not like the water fed into most of the storage reservoirs of the Atlantic slope. The reservoir will not be fed by turbid streams. The material carried in suspension by the incoming waters will be very small.

The seepage loss from a canal planned to come into use without lining is referred to as objectionable. In reply to this criticism of the project, it should be stated, in the first place, that the canal and tunnels can be lined throughout at a moderate cost, but that such lining at the outset was not thought requisite and was not, therefore, included as a feature of the project, nor was it covered by the cost estimate. In the second place, the seepage loss from the canal, except only the last few miles, which are out on the plain between the Tuolumne River and Dry

* See the analysis given in the paper.

Creek, will be return water to the river and available for use of the irrigation districts, whose headworks are lower down on the stream and whose prior rights San Francisco will always respect. In the third place, the canal should, and undoubtedly will, go into service at a flow in excess of the required delivery, so that ordinary seepage loss will not interfere with the delivery of the amount of water required until the time comes when this quantity approaches the canal capacity, and then the canal will be lined. The only seepage that will prove to be a total loss will be that from a few miles of canal below the point where the canal leaves Tuolumne River. This stretch of canal, moreover, will be the only portion of the conduit in which there will be the shallow water which Mr. Stearns has assumed for the full length of the canal.

The canal was not planned with cover throughout because it is located for the most part along a steep, rocky cañon wall and can be made inaccessible to grazing stock throughout its length, but the cover can be added as required. Where crossed by trail or road the canal will, of course, be suitably protected from blowing dust.

The writer does not wish to be understood as having made a strong plea for unlined canals for municipal water supply, and the presentation of a project with any part of the canal unlined is the result of a consideration of local conditions, with due weight given to the added cost of lining the canal.

The portion of the river which will convey the water from the Hetch Hetchy reservoir to the diverting dam is not of the character of an ordinary valley stream. The portions of Tuolumne River, of Eleanor Creek and of Cherry Creek, which are to convey the water from the reservoirs to the diverting dam, lie in deep rock-bound cañons, in which human activities will probably never extend beyond such as relate mainly to a future utilization of these streams for power purposes. Cherry Creek is a high mountain stream whose watershed lies almost entirely within the National Forest reserve, for the most part at elevations of 5 000 to 10 000 ft. This stream is fed by the outflow of numerous glacial lakes, to which artificial reservoirs will, no doubt, be added as the utilization of the water for power becomes of value. It is a stream on which there is not a single resident and on which there never should be any objectionable activity.

Whether a canal only partly lined and partly under cover will be adequate to preserve the high quality of the water, or whether it may be found advisable to keep the water under

cover in lined conduits after diversion from the river, it is confidently believed that from Tuolumne River as a source, water of exceptional quality not requiring treatment can be delivered to San Francisco.

The possibility of expanding the present water works by adding other coast range sources of supply has been admitted. It remains to be added that the presentation of a tentative estimate of ultimate output of the nearby sources of water does not mean that it is certain that these sources can be developed to the indicated limit for use in San Francisco. The estimate is coupled with much uncertainty. It was made, as stated in the paper, to show that the possible expansion of the Spring Valley Water Company's system is not inconsiderable.

Association of Engineering Societies.

Vol. XLI.	AUGUST, 1908.	No. 2.

PROCEEDINGS.

Louisiana Engineering Society.

June, 1908. — The Society decided to promote the passage, by the Louisiana Legislature, of a bill to regulate the practice of civil engineering and surveying, and it appointed a Legislative Committee to look after its interest. The bill originated in the Society and was endorsed by the Society in May, 1902, to which reference was made in the Journal of the Association of Engineering Societies, Vol. XXX, No. 1, for January, 1903; Proceedings of Louisiana Engineering Society, pages 7 and 9.

July, 1908. — The following is a copy of the Act passed (No. 308).

Senate Bill No. 135. [By Mr. Favrot.]

AN ACT

To regulate the Practice of Civil Engineering and Surveying; to create a State Board of Engineering Examiners, and regulate the Fees and Emoluments thereof; to prevent the Practice of the Said Callings or Professions by Unauthorized Persons; and to provide for the Trial and Punishment of Violators of the Provisions of this Act by Fine or Imprisonment; and to repeal All Laws or Parts of Laws in Conflict or Inconsistent with This Act.

Section 1. Be it enacted by the General Assembly of the State of Louisiana, That, from and after the promulgation of this Act, no person excepting those already engaged under existing laws in the practice of Civil Engineering and Surveying, shall practice the said callings or professions within the State of Louisiana, unless such person shall possess all the qualifications required by this Act.

Section 2. Be it further enacted, etc., That after the promulgation of this Act, any person before entering upon the practice of Civil Engineering or Surveying shall present to the Board of Engineering Examiners, as hereinafter constituted, a diploma from an engineering college or school of good standing, said standing to be determined by the Board, or shall pass a satisfactory examination before the Board upon the following, to wit:

For Surveying: Geometry, Trigonometry, Land Surveying, Practical Use of Instruments.

For Civil Engineering: Same as surveying; in addition thereto, Natural Philosophy or Physics.

The person shall also satisfy the Board that he is twenty-one years of age, of good moral character, and possess at least a fair primary education. If said diploma or examination are satisfactory to the Board, they shall issue to such person a certificate in accordance with the facts.

SECTION 3. Be it further enacted, etc., That the Engineering Examiners shall consist of a Board of five members, three of whom shall constitute a quorum for the purpose of holding examinations and granting certificates. All members shall be practicing Civil Engineers or Surveyors of good standing. The certificate of the Board shall be conclusive proof of efficiency of the applicant. All examinations held by the Board, and answers of applicants, shall be in writing and shall be filed and kept as records. All members shall be appointed by the Governor of the State from a list presented by the Louisiana Engineering Society, and the Governor shall have the right to remove any or all members thereof for inefficiency or neglect of duty, and to fill all vacancies occurring in the Board from names recommended by the Louisiana Engineering Society.

SECTION 4. Be it further enacted, etc., That the first Board of Engineering Examiners appointed under this Act shall meet and organize within thirty days from the date of their appointment, and shall name one member to serve two years, one to serve three years, one to serve four years, one to serve five years, and one to serve six years, to be decided by lot or agreement among themselves as to their respective terms.

At the expiration of the above terms, each member shall be appointed by the Governor for a term of six years from names recommended by the Louisiana Engineering Society.

SECTION 5. Be it further enacted, etc., That all persons practicing Civil Engineering or Surveying in the State of Louisiana before the passage of this Act shall, within ninety days after its promulgation, register as such practitioners with the Clerk of the District Court of the Parish within which they reside, and, upon the appointment of the Board of Engineering Examiners, shall notify the said Board of such registration.

SECTION 6. Be it further enacted, etc., That to prevent delay and inconvenience, any one member of the Board may grant a permit to practice after a satisfactory examination of any applicant, and shall report thereon to the next regular meeting of the Board. Said temporary permit shall not continue in force longer than until the next regular meeting, and shall in no case be granted less than six months after the applicant has been refused a permit by the Board.

SECTION 7. Be it further enacted, etc., That all certificates issued under Section 2 of this Act must be recorded in the office of the Clerk of the District Court of the Parish in which the applicant resides, who shall make recordation thereof in a book to be kept for this purpose only, and who shall certify to said recordation by endorsement on original certificate, which the holder shall then deliver or transmit to the Board of Engineering Examiners. The fee which the clerk is entitled to charge for such recordation shall be one dollar. Said certificate entitles the holder to be placed on the list of regular Civil Engineers and Surveyors, the publication of which is hereinafter provided for. The Board of Engineering Examiners shall preserve the certificates, and a copy signed by its Secretary shall be received as evidence in courts. Until recordation of said certificate, the holder shall not practice Surveying or Civil Engineering in the State of Louisiana.

SECTION 8. Be it further enacted, etc., That the Board of Engineering Examiners shall publish annually a complete list of registered civil engineers and surveyors, with their residences, in a daily paper of the City of New Orleans, and such published list shall be received as evidence in court that the names it contained are duly registered.

SECTION 9. Be it further enacted, etc., That the members of the Board of Engineering Examiners shall receive in compensation for their duties ten dollars per day during the session of the Board, together with their hotel bills and their traveling expenses by the most direct route to and from their respective residences; the same to be paid out of any

moneys in the treasury of the Board, upon the certificate of the president and the secretary. The Board is empowered to demand a fee of one dollar for issuing a certificate, and ten dollars for examination. If the applicant fails to pass, and no certificate is issued, five dollars of his fee is to be retained. The fee for a temporary permit shall be five dollars, and is to be credited to the applicant when he applies for a permanent permit.

SECTION 10. Be it further enacted, etc., That any person who shall practice or attempt to practice the profession or calling of a civil engineer or surveyor, without having complied with the provisions of this Act, shall be fined not less than twenty-five dollars, not more than one hundred dollars, or shall be imprisoned not less than thirty nor more than ninety days, for each offense by any court of competent jurisdiction.

SECTION 11. Be it further enacted, etc., That the Board may revoke any permit it has issued, when its holder has been convicted of immoral conduct before a competent court.

SECTION 12. Be it further enacted, etc., That this Act shall not apply to the Engineering Departments of the United States, nor to the Civil Engineers and Surveyors of other States and Territories when in actual consultation with registered Civil Engineers or Surveyors of this State, nor to any Civil Engineer or Surveyor of this State actually practicing such profession or calling before the passage of this Act.

SECTION 13. Be it further enacted, etc., That the Board of Engineering Examiners shall make annual report to the Governor of its transactions, with such recommendations for the advancement of the services as it may think best.

SECTION 14. Be it further enacted, etc., That all laws or parts of laws in conflict with this Act be and the same are hereby repealed.

P. M. LAMBREMONT,
Lieutenant-Governor and President of the Senate.

H. G. DUPRE,
Speaker of the House of Representatives.

Approved July 9, 1908.

J. Y. SANDERS,
Governor of the State of Louisiana.

Technical Society of the Pacific Coast.

SAN FRANCISCO, AUGUST 28, 1908. — A regular meeting was held at Blanco's restaurant on O'Farrell Street. About thirty members and guests sat down to a dinner which was served at 6.30 o'clock.

Immediately after the dinner the President, Mr. George W. Dickie, called the meeting to order. The Secretary read the minutes of the last regular meeting of June 5, which were approved.

The President thereupon announced the papers of the evening, as follows:

1. The Use of Asphaltum, by Harry L. Larkin (to be read). 2. The Auxiliary Water Supply of San Francisco, by H. D. Connick (to be discussed). 3. Practical Methods of Fitting up a Hydraulic Mine, by H. A. Brigham (to be read). 4. The Water Supply of San Francisco, by C. E. Grunsky (to be read).

The President announced that the paper by Mr. Larkin would be read at this meeting and its discussion taken up at the next regular meeting of

October, and that the discussion of Mr. Connick's paper would follow the reading of Mr. Larkin's.

Mr. Harry Larkin was called upon and he read an interesting account of "The Use of Asphaltum for Commercial and Practical Purposes."

Mr. Tom W. Ransom began the discussion of Mr. Connick's paper on "The Auxiliary Water Supply of San Francisco." He was followed by the President, Mr. Dickie, who took up a number of the individual features for a general discussion. Mr. Connick responded at length, giving explanations and reasons for the various arrangements that had been considered necessary to meet all the demands of the city. Others followed along the line of the discussion, Mr. Molera, Mr. Morrin and a guest on behalf of the underwriters, who explained certain conditions under which the insurances of the city were greatly reduced.

The meeting was adjourned at eleven o'clock.

Attest,

OTTO VON GELDERN, *Secretary.*

ASSOCIATION

OF

ENGINEERING SOCIETIES.

VOL. XLI. **SEPTEMBER, 1908.** No. 3.

PROCEEDINGS.

Engineers' Club of St. Louis.

ST. LOUIS, JUNE 3, 1908. — The 653d meeting of the Engineers' Club of St. Louis was held in the auditorium of the Manual Training School, Von Verson Avenue, near Union Avenue, on Wednesday evening, June 3, 1908, President Brenneke presiding. There were present thirty-eight members and thirty-three visitors, among the latter a large number of ladies.

There being no objection, the minutes of the last meeting were not read.

The application of Mr. Oliver B. Barrows for associate membership, having been duly approved by the Executive Committee, was submitted to ballot, and Mr. Barrows was unanimously elected.

The President then introduced Prof. C. M. Woodward, who presented a very interesting illustrated address on the building of the Eads Bridge. Professor Woodward described in considerable detail the plan adopted for sinking the piers as well as the methods used in erecting the arches. Especial emphasis was laid on the great originality displayed by Captain Eads and his associates in overcoming the numerous difficulties encountered in this pioneer work.

At the conclusion of the address it was voted to extend the thanks of the Club (*a*) to the officers of the St. Louis Electrical Bridge Company and to the Missouri Valley Bridge and Iron Company for the courtesy extended on the occasion of the Club's visit to the McKinley Bridge on May 9; (*b*) to the officers of the St. Louis Portland Cement Company and the Union Sand and Material Company for the hospitable entertainment of May 23, when the Club was invited to visit the plant of the St. Louis Portland Cement Company; and (*c*) to Prof. C. M. Woodward for his kindness in presenting the interesting address on the building of the Eads Bridge, and to the authorities of the Manual Training School for the privilege of holding the meeting of June 3 in the auditorium of that school.

The meeting then adjourned to the dining room of the school, where refreshments, arranged for by the Entertainment Committee, were served.

A. S. LANGSDORF, *Secretary.*

Utah Society of Engineers.

SALT LAKE CITY, UTAH, SEPTEMBER 18, 1908. — The regular monthly meeting held in rooms of Commercial Club, Salt Lake City, evening of September 18, was devoted to a discussion of the subject of "Engineering Ethics."

Discussion was opened by Mr. J. C. Hornung, resident engineer of the Salt Lake Public Service Company, and by Mr. R. E. Caldwell, of the Western Engineering Company, and was participated in by Messrs L. C. Kelsey, A. O. Gates, Dr. Lyman, A. P. Merrill, Professor Overstrom, Sidney Bamberger and J. F. Merrill. The discussion was spirited and thorough and a committee was named to investigate the matter and make report as to the advisability of drafting a code applicable to local conditions. There was quite a large attendance of practicing engineers.

The next regular meeting of the society will be held in the Physics building of the University of Utah on the third Friday of October, when a paper will be presented by Mr. R. S. McCaffery, metallurgical director of the Knight Smelter, on the subject of "Connerville and Centrifugal Blowers for Blast Furnaces."

Adjourned.

D. McNICOL, *Secretary.*

Association of Engineering Societies.

Vol. XLI. | OCTOBER, 1908. | No. 4.

PROCEEDINGS.

Engineers' Club of St. Louis.

St. Louis, September 16, 1908. — The 654th meeting of the Engineers' Club of St. Louis was held at the Club rooms, 3817 Olive Street, on Wednesday evening, September 16, 1908, President Brenneke presiding. There were present sixteen members and six visitors.

The minutes of the 652d and 653d meetings were read and approved. The minutes of the 442d, 443d and 444th meetings of the Executive Committee were read.

The Secretary read an application for membership from Mr. Montgomery Schuyler.

A communication from Messrs. Breed and Hosmer, announcing the donation of Vol. II of their book on the Principles and Practice of Surveying, was read. The Secretary was instructed to make due acknowledgment of the gift.

The resignation of Mr. W. V. N. Powelson as a member of the Executive Committee, due to removal from the city, was read and accepted. The President then called for nominations for the vacancy created by Mr. Powelson's resignation, and Mr. Wall nominated Mr. C. A. Moreno, On motion of Mr. Colnon, duly seconded and carried, the Secretary cast the ballot of the meeting for Mr. Moreno.

The paper of the evening, entitled "Some Details of Gas Distribution," was then presented by Mr. J. D. Von Maur. The distributing mains of the Laclede Gas Light Company of St. Louis were described in detail, with special reference to the means employed to maintain a steady pressure at the service taps; this is accomplished through the use of high-pressure mains which supply the low-pressure mains through reducing valves. One of these reducing valves was exhibited, as well as a specially constructed glass meter arranged to show the mechanism.

A discussion of the paper was participated in by Messrs. W. A. Baehr, H. H. Humphrey, W. G. Brenneke and R. S. Colnon.

Adjourned.

A. S. Langsdorf, *Secretary*.

St. Louis, October 7, 1908. — The 655th meeting of the Engineers' Club of St. Louis was held at the Club rooms, 3817 Olive Street, on Wednesday evening, October 7. President Brenneke presided. There were present thirty-four members and eight visitors.

The minutes of the 654th meeting were read and approved, and the minutes of the 446th meeting of the Executive Committee were read.

Mr. Montgomery Schuyler was elected to membership, and applications were read from the following: Edward Eugene Green (member); Charles Wescott Gennet, Jr. (member); Ernest Linwood Ohle (member); Raymond Glime Alexander (member).

The paper of the evening on the "Electrolysis of Reinforced Concrete" was presented by Prof A. S. Langsdorf. The paper gave the results of two series of tests, twelve specimens having been used in each series. The specimens were connected in series and were subjected to the action of a direct current (0.05 amperes in the first series and 0.2 amperes in the second), which was continued for seventy days in series one and thirty days in series two. In both series there was a loss of weight of the steel which increased in proportion to the time, together with a deterioration and cracking of the concrete. The specimens were placed in earthenware jars and were immersed in fresh water to within half an inch of the top of the concrete.

The paper was discussed and questions were asked by a large number of those present.

Mr. C. A. Bulkeley announced, on behalf of the Entertainment Committee, that an excursion to the new steel plant of Gary, Ind., was being projected by the committee.

Adjourned.

A. S. Langsdorf, *Secretary.*

Boston Society of Civil Engineers.

Boston, June 17, 1908. — At the hour named in the call for the regular meeting this evening, a quorum not being present, the meeting was not called to order.

S. E. Tinkham, *Secretary.*

Bretton Woods, N. H., July 4, 1908. — A special meeting of the Society was held at the Mount Pleasant House, President J. R. Worcester in the chair; twenty-five members and guests present.

In the absence of the Secretary, Mr. Irving T. Farnham was appointed Secretary *pro tem.*

The subject for discussion was, "Why do not Engineers take a more prominent part in public affairs?" The President made the opening address and introduced the following speakers: Mr. George B. Francis, Past President Dexter Brackett, Mr. Morris Knowles and Past Presidents Frank W. Hodgdon and William E. McClintock. After a few closing remarks by the President, the meeting adjourned.

Irving T. Farnham, *Secretary pro tem.*

[The addresses will be printed in an early number of the Journal of the Association of Engineering Societies.]

Boston, Mass., September 16, 1908. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.30 o'clock p.m., President J. R. Worcester in the chair; sixty-nine members and visitors present.

The records of the last regular meeting and of the special meeting of July 4 were read and approved.

Messrs. James R. Baldwin, John V. Beekman, Jr., Armand W. Benoit, Harold D. Jones, James M. McNulty, Luis G. Morphy, Alfred W. Parker, Henry B. Pratt, Harry E. Sawtell, and Gilbert Small were elected members of the Society.

Mr. E. W. Howe called attention to the fact that the Board of Harbor and Land Commissioners had no authority by which it could keep on sale the atlas sheets of the map of the Commonwealth prepared by the United States Geological Survey, and suggested that as it has been a great convenience to engineers to be able to purchase these sheets from the board, it would be well to petition the Legislature that authority be given the board to keep a stock of the sheets on sale at all times.

On motion, it was voted to authorize its officers to sign the petition on behalf of the Society.

Mr. Benjamin Fox gave a very full description of a foundation put in by him where cast reinforced concrete piles were used. Mr. Sanford E. Thompson followed with notes of tests which he had made with regard to driving these piles.

Mr. M. M. Cannon, member of the American Society of Civil Engineers, gave a very interesting talk describing the construction of the Steamship Terminals at Brunswick, Ga., and the pier at the Navy Yard, Charleston, S. C., with special reference to the concrete piles used in those structures. Lantern slides were used to illustrate the descriptions given by the speakers.

After passing a vote of thanks to Mr. Cannon for his kindness in presenting the subject before the Society, the meeting adjourned.

S. E. Tinkham, *Secretary.*

Boston, October 21, 1908. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.35 o'clock p.m., President Joseph R. Worcester in the chair. Fifty-eight members and visitors present.

The record of the last meeting was read and approved.

Messrs. Edward E. Albee, Hermon R. Bliss, Alvin W. King, Charles H. Pease, Ralph E. Rice, Ralph B. Saunders, Albert T. Sprague, Jr., Herman F. Tucker and George S. Whitehead were elected members of the Society.

The President announced the death of Irving T. Farnham, a director of the Society, which occurred on September 19, 1908. On motion of Mr. French, the Chair was requested to appoint a committee of three to prepare a memoir. The Chair appointed as that committee, Messrs. Charles W. Sherman, Henry D. Woods and Charles W. Ross.

The President also announced that a vacancy existed in the office of director for the term expiring in March, 1909, occasioned by the death of Mr. Farnham, and, on motion of Mr. Howe, it was voted that the vacancy be filled at the next meeting of the Society.

Mr. Cowles, for the Committee on Larger Membership and Clubhouse, submitted and read its report.

On motion of Mr. Winslow, it was voted that the report be referred to the next meeting for discussion and that it be printed in the November *Bulletin*.

It was also voted that the thanks of the Society be extended to Mr. Vernon V. Skinner, Penal Commissioner of Boston, for courtesies shown members of the Society on the trip to Deer Island on October 21, 1908.

The President then introduced Dr. Edward V. Huntington, professor of mathematics at Harvard University, who, with the aid of lantern slides, gave a very interesting lecture entitled, "A Study of the Motion of the Gyroscope, with special reference to the Brennan Mono-Rail Car."

Prof. Ira N. Hollis followed with a description of the application of the gyroscope to the Howell Torpedo.

After passing a vote of thanks to Professor Huntington for his interesting lecture on the gyroscope, the Society adjourned.

S. E. Tinkham, *Secretary.*

Sanitary Section.

A regular meeting of the Sanitary Section was held at the Boston City Club, October 7, 1908. Messrs. Gardner S. Gould and Raymond W. Parlin were elected members of the Section.

Mr. Harry W. Clark, chemist of the Massachusetts State Board of Health, gave an interesting account of his observations of sewage disposal works in England and on the continent during a recent trip to those countries. The paper was discussed by Leonard P. Kinnicutt, Earle B. Phelps, Mr. Pitman of the Baltimore Sewerage Commission, and others.

A committee of three was appointed by the Chair to make nominations for a clerk to take the place of Irving T. Farnham, deceased. As a result of the ballot, Robert Spurr Weston was elected Clerk of the Section.

Robert Spurr Weston, *Clerk.*

Report of Committee on Larger Membership and Clubhouse.

Boston, October 21, 1908.

To the Members of the Boston Society of Civil Engineers:

The special Committee on Larger Membership and Clubhouse, which was appointed "to investigate and report upon the question of securing new quarters along the lines outlined in the communication of Mr. L. S. Cowles, of March 18, 1908," begs leave to offer the following report:

CLUBHOUSE.

Your committee deems it desirable for the Society to own a clubhouse, but fears it is not sufficiently strong financially to undertake the acquisition of a suitable property at the present time. With additional funds and a larger membership such a house might be provided and successfully conducted. Its acquisition might be effected by means of the "Permanent

Fund " of the Society, but your committee feels that it would be unwise to recommend such a purchase unless the fund (now about $22 000) amounted to at least 75 per cent. of the total outlay. Further, there should be very favorable prospects of materially increasing the membership in the near future.

From an investigation of property values in Boston, it appears that $50 000 will be required for a suitable property, including necessary alterations. Seventy-five per cent. of this amounts to $37 500, thus requiring an increase of over $15 000 in the Permanent Fund before such a purchase should be attempted. A mortgage of $12 500 would hardly be considered a heavy burden on the property. To increase the Permanent Fund to this extent, and to provide sufficient income to successfully manage affairs after the acquisition of the building, will require a much larger membership than at the present time. While the possession of a permanent home for this Society would doubtless greatly increase the membership, your committee is of the opinion that the Society cannot safely venture upon such an undertaking until such larger membership has been in part secured.

The present quarters offer slight inducement towards increased membership or towards sociability among the present members. Because of this and on account of insufficient finances to acquire a building of our own, your committee would recommend a search for and, if possible, a lease of quarters better adapted to the needs of this Society. It would be advisable to invite the New England Water Works Association and the New England Association of Gas Engineers to coöperate with us in this undertaking. Your committee believes that the plan outlined by a former committee was a step in the right direction, but was too uncertain of attainment, and was handicapped by an unfavorable location (Broad Street). The present committee has so far been unsuccessful in finding a suitable building that offers quarters more desirable than those now occupied by the Society, and recommends that the Special Committee on Quarters be instructed that it is the desire of this Society that more convenient quarters be secured, and that said committee take up the active consideration of this subject and report to the Society at the earliest opportunity.

LARGER MEMBERSHIP.

Inasmuch as a permanent home is desirable and can be secured only through a larger membership, it behooves the Society to take active steps to increase the number of its members. Equally important with the question of more suitable quarters is that of making the Society more attractive to individual members. Increased sociability and a manifest interest of one member in another are needed, both to retain present members and to attract new men. If " the encouragement of social intercourse among engineers and men of practical science " is to continue to be one of the objects of this Society, then more attention should be paid this feature than is being given it at the present time. Better quarters will prove a strong move in this direction.

Efforts should be made to become better acquainted with out-of-town members and to make them acquainted with a larger number of local men. With more convenient quarters, where cards and games might be enjoyed, in addition to the library privileges, the members would surely

experience a certain social intercourse that is now lacking. As a means tending to increase the attractiveness of the Society at the present time, your committee offers the following suggestions:

(1) Establishing a Bureau of Registration for those members seeking employment or a change in position.

Remarks. — While our object as a Society, as set forth in the Constitution, is not necessarily a benevolent one, at the same time a slight effort on our part to aid such members as are unfortunate enough to be temporarily without employment seems only just.

(2) Additional informal meetings, where subjects may be taken up and discussed in a free manner, such discussions not necessarily to be reserved for publication.

Remarks. — The experience of your committee has been that many members are not inclined to enter freely into the discussion at the formal meetings. While this may be due to the proverbial modesty of the engineer, this modesty has been laid aside at many of our informal meetings. These occasions are as a rule largely attended because of their informality and because of the detailed and elementary manner in which the subjects are frequently presented. It is suggested that some of these meetings might acceptably take the form of informal lectures on the elements of various engineering subjects, such as theory of structures, sanitary engineering, reinforced concrete, etc.

(3) Sending our present *Bulletin*, *gratis*, to various large engineering offices in New England.

Remarks. — Such a distribution of our *Bulletin* would certainly be a benefit to the profession at large. The description of current engineering work should prove particularly attractive, as it is the only compilation of that nature of which we are aware. Further, the time of meetings, as well as the subjects to be dealt with, might in this way become known to various engineers, who would otherwise receive such information verbally or not at all. Such distribution would be of additional value to our advertisers whom we must needs depend upon, in a measure, for the success of the publication.

(4) Publication of our proceedings and papers in a journal of our own. This would necessitate our withdrawal from the Association of Engineering Societies.

Remarks. —Your committee fully realizes that this question is a very delicate one, and it is only by examining critically the facts of the case that the above action has been decided upon as being for our best interest. After looking carefully into the financial side of this question, we feel assured that the step advised will not burden the Society with additional financial obligations.

That the foundation of the Association of Engineering Societies was, at the time, a wise proceeding is not to be doubted, and our affiliation with the other societies a right and proper step to take. Conditions have since changed, until our Society now seems to demand a publication more individual in character.

The following table may prove of interest as showing how the various societies comprising the "Association" contributed to Vol. XL of the JOURNAL (January–June, 1908). The figures give the number of pages of reading matter, minutes of meetings not included.

Vol. XL. January–June, 1908.	Boston.	Detroit.	Montana.	St. Louis.	Louisiana.	Pacific Coast.	Total.	Boston.	All Others.	Per Cent. Boston.
January, 1908....	52						52	52		100
February, 1908...	21		33	18	3		75	21	54	28
March, 1908......		31	9			9	49		49	0
April, 1908.......	53			3	10		66	53	13	80
May, 1908........	37						37	37		100
June, 1908.......	21	16	2				39	21	18	54
Vol. XL........	184	47	44	21	13	9	318	184	134	58

NOTE. — St. Paul and Toledo did not contribute.

From the above it is seen that the Boston Society is practically monopolizing the present publication. We firmly believe that the other societies comprising the Association would benefit by our withdrawal. They would then be obliged to do their full duty toward the publication or see its immediate downfall. It should be noted that two societies have furnished no papers for this volume which contains the winter's proceedings.

Our new publication of, say, ten numbers per annum might well supersede the present *Bulletin*, all papers with discussions to reappear in an annual number, suitably arranged and indexed. Would not many of our members who are not now inclined to spend the time to prepare papers for publication in the journal of the Association, take more interest, and perhaps pride, in furnishing such material for our own publication, thus bringing forward valuable matter that might otherwise not be revealed? The papers of the other societies would still be available in their journal.

(5) That an endeavor again be made to form additional "sections" of the Society.

Remarks. — The recent agitation of this subject, which resulted in the formation of the Sanitary Section, has certainly proved a benefit to the Society. This Section has been a success from the start, and your committee sincerely hopes to witness the formation of a Mechanical Section, and possibly others, at an early date.

(6) Annual meeting of the Society to be made more of a function, so that out-of-town members will have incentive to be present. One entire day to be reserved for the event, with (*a*) the annual dinner on the preceding evening; (*b*) registration and annual meeting in the morning; (*c*) excursion in the afternoon; and (*d*) smoker, with light refreshments, in the evening.

Remarks. — At present the only real stated social function that we enjoy is the annual dinner, and that somehow fails to bring out any considerable portion of the non-resident membership. A meeting as suggested would surely give us a splendid opportunity to meet our non-resident members, and so renew acquaintances and make new ones where it is now impossible. An entire day, say the third Wednesday in March, might be devoted to this function. With the annual dinner occurring on the Tuesday night preceding, most of our New England members could

attend all functions with a loss of but one day from their business. Your committee sincerely hopes that the members of this Society will see fit to inaugurate an annual meeting next March that may prove a lasting pleasure to all who may be fortunate enough to attend.

Luzerne S. Cowles,
Charles B. Breed,
George A. Carpenter,
Ralph E. Curtis,
Committee.

Table showing Growth of Civil Engineering Societies.

Canadian Society Civil Engineers.
January, 1904, 1 145
January, 1908, 2 047 Increase in 4 years = 902, or 79 per cent.

American Society Civil Engineers.
January, 1904, 2 924
January, 1908, 4 411 Increase in 4 years = 1 487, or 51 per cent.

Civil Engineers Club of Cleveland.
March, 1904, 211
March, 1908, 276 Increase in 4 years = 65, or 31 per cent.

Connecticut Society Civil Engineers.
May, 1904, 245
May, 1908, 290 Increase in 4 years = 45, or 18 per cent.

Boston Society Civil Engineers.
July, 1904, 585
June, 1908, 660 Increase in 4 years = 75, or 13 per cent.

British Institute of Civil Engineers.
April, 1904, 7 633
April, 1908, 8 573 Increase in 4 years = 940, or 12 per cent.

Louisiana Engineering Society.

New Orleans, October 12, 1908. — The following resolutions were adopted referring to the death, on October 5, of John Clegg, associate member.

"*Whereas*, It has pleased Divine Providence to take from our midst our esteemed fellow-citizen, John Clegg, associate member of the Louisiana Engineering Society, it is fitting that the members of this Society should express their appreciation of his ability as an attorney-at-law; of his high standing as a judge, and of his devotion to the advancement of all professional studies; therefore,

"*Be it resolved*, That this Society has in the death of Judge Clegg, lost one of its most brilliant and talented associate members, and that a sense of personal loss is keenly felt by every member; and be it

"*Resolved*, That a copy of these resolutions be spread upon the records of this Society, and a copy of same be sent to his bereaved family."

"Alf. F. Theard,
"H. L. Zander,
"W. B. Wright,
"*Committee.*"

Utah Society of Engineers.

Salt Lake City, October 16, 1908. — The regular monthly meeting was held on October 16, 1908, in the Physics Building, University of Utah.

Mr. Richard S. McCaffery, lately metallurgical director of the Tintic Smelting Company, gave an interesting talk on " Some Tests on Connerville and Centrifugal Blowers for Blast-Furnace Work."

The subject proved very interesting to the smelter and mine people present, as the employment of centrifugal blowers in smelter operation in the Rocky Mountain region is new practice.

The paper was appreciatively discussed by Messrs. E. B. Bartlett, Prof. G. A. Overstrom and C. F. Moore, chief engineer United States Smelting Company.

The next meeting of the Society will be held November 20 in the Physics Building, University of Utah, when Mr. F. E. Johnson, of the Fairbanks Morse Company, will give an illustrated lecture on " Suction Gas-Producer Plants," and Prof. R. R. Lyman will read a paper on " Quick and Easy Methods of Designing Pipe, and Open Channels for Carrying Water."

Adjourned.

D. McNicol, *Secretary.*

Association of Engineering Societies.

Vol. XLI. **NOVEMBER, 1908.** No. 5.

PROCEEDINGS.

Engineers' Club of St. Louis.

St. Louis, October 21, 1908. — The 656th meeting of the Engineers' Club of St. Louis was held at the Club rooms, 3817 Olive Street, on Wednesday evening, October 21, President Brenneke presiding. There were present twenty-nine members and four visitors.

The minutes of the 655th meeting were read and approved. The minutes of the 447th meeting of the Executive Committee were read.

The Secretary read a letter from Mr. S. Bent Russell announcing the presentation to the Club of a set of reports of the Board of Public Improvement of St. Louis.

An application for membership was read from Mr. John T. Garrett.

The following were elected: Raymond Glime Alexander (member), Charles Wescott Gennett, Jr. (member), Edward Eugene Green (member), Ernest Linwood Ohle (member).

Mr. C. A. Bulkeley, chairman of the Entertainment Committee, made a statement of the plans for the trip to Gary, Ind. On the suggestion of Mr. W. A. Layman, the Secretary was instructed to write to the Secretary of the Western Society of Engineers, informing him of the proposed trip.

The paper of the evening, on " The New Seven-Foot Steel Flow Line from Baden to the Chain of Rocks," was presented by Mr. W. H. Henby. The paper gave a good description of the plans and construction of the flow line, illustrated by numerous slides, and included a summary of the cost of the work.

The discussion that followed the reading of the paper was participated in by a large number of those present.

Adjourned.

A. S Langsdorf, *Secretary.*

St. Louis, November 4, 1908. — The 657th meeting of the Engineers' Club of St. Louis was held at the Club rooms on Wednesday evening, November 4. Vice-President E. E. Wall presided. There were present twenty-two members and two visitors.

The minutes of the 656th meeting were read and approved and the minutes of the 448th meeting of the Executive Committee were read.

Mr. John T. Garrett, on ballot, was elected to membership.

Applications for membership were read from the following: W. A. Heimbuecher, C. B. Lord.

The Secretary read a letter from Mr. Richard McCulloch, inviting members of the Club to inspect a section showing different methods of paving T-rail track, this exhibit being installed at the Park and Van Deventer office of the United Railways Company. A letter was also read from Miss Mary Klemm, librarian in the Academy of Science, announcing that the Academy desired to secure a tenant for one of the rooms in the building.

The following were nominated for the Nominating Committee: C. W. Childs, Edward Flad, R. L. Murphy, William Elliott, A. L. Jacobs.

A motion, duly seconded, to close the nominations was carried. It was unanimously voted that the rules be laid aside and that the Secretary cast the ballot of the meeting for the election of the Nominating Committee as above constituted.

Mr. W. W. Horner then presented the paper of the evening on the "Design and Constructional Features of the Harlem Creek Sewer." The paper described in detail the various sections adopted for different parts of the sewer, and included a description of the constructional methods employed on various parts of the work. The paper was freely illustrated by numerous lantern slides.

The discussion was participated in by Messrs. B. H. Colby, E. E. Wall, W. S. Henry, A. P. Greensfelder and R. H. Phillips.

Adjourned.

A. S. Langsdorf, *Secretary.*

Technical Society of the Pacific Coast.

San Francisco. — Regular meeting held Friday, November 6, 1908, President George W. Dickie in the chair. The meeting was called to order immediately after dinner, which was had at the Argonaut Hotel, about twenty members being present. The minutes of the last regular meeting of the Society were read and approved.

The Secretary read the following applications for membership, which were ordered to take the usual course: George Fisher Beardsley, metallurgist, Fruitvale, Cal.; J. W. White, electrical engineer, Atlas Building, San Francisco.

The Secretary read the following letter, which he explained as having been written after hearing of the death of Mr. George E. Dow, who died in Berlin in the middle of October.

San Francisco, October 19, 1908.

To the George E. Dow Company,
San Francisco:

Sirs, — The Technical Society has heard with great regret of the death of Mr. George E. Dow, one of its most esteemed members, and the

Secretary has been instructed to communicate with you and to offer to the family and to those nearest and dearest to him the expressions of deepest sympathy.

It seems particularly unfortunate that Mr. Dow should die at a time when in the rehabilitation of this great city a man of his type and energy could least be spared. He was in the prime of his life, and his useful career should not have been ended for many years to come. To close it suddenly, when not yet sixty years of age, is tragic and much to be lamented.

Expressing again the sympathies of all his engineering colleagues to his family and business associates, I am, for the Society, as well as on my own behalf,

Yours faithfully,
(Signed) OTTO VON GELDERN, *Secretary.*

The action of the Secretary in this matter was approved, and he was instructed to communicate with the relatives of the late Mr. Dow for the purpose of obtaining data to write a suitable memorial for publication in the JOURNAL.

The members present thereupon chose the following Nominating Committee to prepare a ticket of officers for the ensuing year, and to submit it to the Society at the time of the next regular meeting of January: H. A. Brigham, chairman; Heinrich Homberger, Leon S. Quimby, Harry Larkin and L. S. Griswold.

Mr. Beardsley thereupon discussed the paper presented at the last regular meeting by Mr. Harry Larkin on the "Use of Asphaltum," dwelling on the use of coal tar in Australia for similar purposes, and Mr. Larkin addressed the Society further on the same subject in explanation of the commercial value of the proper product, emphasizing the fact that coal tar will penetrate to some extent and that asphaltum is nothing more or less than a protective coating or blanket without penetrating qualities.

The paper by Mr. H. A. Brigham, read by title at the last regular meeting, on the subject of "Methods of Hydraulic Mining," was taken up. The President read the paper by extracts, dwelling upon the individual features of the subject sufficiently to establish the points of the author. The paper proved an extremely interesting one, as it brought up the old methods of gold washing that had not been discussed by the Society for many years, and this aroused an interest in the older members who had had more or less acquaintance in their day with hydraulic mining.

Mr. W. W. Waggoner, of Nevada City, discussed the paper by letter from the standpoint of the hydraulic miner. The letter was read by the Secretary, after which a general discussion took place.

The members presented a vote of thanks to the author, Mr. Brigham, for his very detailed and exhaustive paper, which, when published, will tend to perpetuate the valuable practical experiences of an old hydraulic miner.

The meeting thereupon adjourned to meet in January, 1909.

OTTO VON GELDERN, *Secretary.*

Utah Society of Engineers.

Salt Lake City, Utah, November 20, 1908. — The November meeting was held in Physics Building, University of Utah. There were about thirty local engineers present, and a highly interesting and instructive paper was presented by Mr. F. E. Johnson dealing with "Gas Producer Plants." Slides were shown, picturing suction producers in the making and in their various applications as prime movers. Dr. R. R. Lyman gave a short but valuable talk on "Quick and Easy Methods of Designing Pipe and Open Channels for Carrying Water."

The diagrams of Professor Church were illustrated as applied in the solving of water channel problems.

Three applications for membership were presented and acted upon favorably, the gentlemen admitted being Mr. R. E. Jerrault, Wm. A. Black and Leonard Wilson.

Messrs. E. A. Wall and L. E. Riter were named as the Society's representatives to attend the National Mining Congress at Pittsburg.

As authorized at the September meeting, President Merrill appointed the following-named gentlemen to act as a committee to consider the question of "Ethics" and to report their recommendations to the Society at a later meeting: H. P. Saunders, Ben. F. Tibby, Prof. G. A. Overstrom, R. E. Caldwell, Sidney Bamberger.

Association of Engineering Societies.

Vol. XLI. **DECEMBER, 1908.** No. 6.

PROCEEDINGS.

Engineers' Club of St. Louis.

St. Louis, November 18, 1908. — The 658th meeting of the Engineers' Club of St. Louis was held at the Club rooms on Wednesday evening, November 18, 1908. President W. G. Brenneke presided. There were present about thirty-five members and twenty-five visitors, of whom many were ladies.

In calling the meeting to order, the President stated that the Executive Committee had decided to make the meeting take the form of an open one, in celebration of the fortieth anniversary of the first meeting of the Club, which occurred in November, 1868. He referred to the past history of the Club and bespoke for it a continued growth in membership and influence.

On motion, duly seconded, it was voted to dispense with the usual order of business, with the exception of the report of the Nominating Committee which was due to be presented at this meeting, according to the provisions of the By-Laws. The Secretary then read the following letter which had been received from the Chairman of the Nominating Committee:

St. Louis, November 16, 1908.

Mr. A. S. Langsdorf,
Secretary Engineers' Club of St. Louis,
3817 Olive Street, City.

Dear Sir, — The Nominating Committees, having selected one candidate for each office for the ensuing year, as is provided in Section No. 11 of the By-Laws, hereby report to the Club their selections as follows:

President — E. E. Wall.
Vice-President — R. S. Colnon.
Secretary and Librarian — A. S. Langsdorf.
Treasurer — E. B. Fay.
Two Directors — C. A. Moreno and Carl Gayler.
Three Members of the Board of Managers of the Association of Engineering Societies — O. W. Childs, J. T. Dodds, Samuel Trepp.

Respectfully yours,

O. W. Childs,
Edward Flad,
R. L. Murphy,
William Elliott,
A. I. Jacobs,
Nominating Committee.

Per O. W. Childs, *Chairman.*

The President then introduced the speaker of the evening, Prof. Holmes Smith, of Washington University, who adressed the meeting on the subject "Constructional Features of the Gothic Cathedrals." The speaker traced the development of the finest examples of Gothic cathedral architecture from the early Roman Christian churches, which, in their turn had been developed from the prevailing style of Roman architecture for dwelling purposes. It was shown how, as the churches increased in size, the roof was changed from the ordinary flat timber construction to the semi-circular stone arch, then to the pointed arch, and finally to the groined arch. In this connection it was also shown how the lateral support for the arches gradually developed from a crude form of barrel vault to the graceful flying buttress. The address was very freely illustrated by lantern slides.

At the conclusion of the address the meeting adjourned to the adjoining rooms where refreshments were served.

A. S. LANGSDORF, *Secretary.*

ST. LOUIS, DECEMBER 2, 1908. — The annual meeting of the Engineers' Club of St. Louis was held at the Club rooms on Wednesday evening, December 2, 1908, at 8.30 o'clock, Vice-President E. E. Wall presiding. There were present twenty-one members and one visitor.

The minutes of the 657th and 658th meetings were read and approved. The minutes of the 449th, 450th and 451st meetings of the Executive Committee were read.

The following applications were presented: Wahlers, Ernest A. C. (associate member); Davis, W. Harding (associate member).

The following were elected: Heimbuecher, W. A. (member); Lord, C. B. (associate member).

The chairman announced that additional nominations for officers might be made by written request signed by five members. No such additional nominations were made, thus leaving the nominations for the different offices as follows:

For President — E. E. Wall.
Vice-President — R. S. Colnon.
Secretary and Librarian — A. S. Langsdorf.
Treasurer — E. B. Fay.
Directors — C. A. Moreno, Carl Gayler.
Members Board of Managers, Association of Engineering Societies — O. W. Childs, J. T. Dodds, Samuel Trepp.

Annual reports were then presented by Mr. W. G. Brenneke, chairman of the Executive Committee; Mr. A. S. Langsdorf, secretary; Mr. O. F. Harting, treasurer; Mr. A. S. Langsdorf, librarian; Mr. R. L. Murphy, chairman of the Board of Managers; Mr. C. A. Bulkeley, chairman of the Entertainment Committee, and Mr. A O. Cunningham, chairman of the Membership Committee. All of the reports were received and filed. The chairman stated that the report of the Treasurer would be further considered by the Executive Committee and audited according to the usual practice.

Adjourned.

A. S. LANGSDORF, *Secretary.*

St. Louis, December 16, 1908. — The annual dinner of the Engineers' Club of St. Louis was held on Wednesday evening, December 16, 1908, at 7.30 p.m., at the Mercantile Club. There were present thirty-three members and seven guests. Among the latter, four were guests of individual members, and three, namely, Mr. Arthur N. Sager, Prof. C. A. Waldo and Dr. David Franklin Houston, were the guests of the Club.

At the conclusion of the dinner President W. G. Brenneke announced that as a result of the letter ballot for the election of officers the following had been elected:

President — E. E. Wall.
Vice-President — R. S. Colnon.
Secretary and Librarian — A. S. Langsdorf.
Treasurer — E. B. Fay.
Directors — C. A. Moreno, Carl Gayler.
Board of Managers, Association of Enginneering Societies — O. W. Childs, J. T. Dodds, Samuel Trepp.

Mr. Brenneke then introduced the new President, Mr. E. E. Wall, who then presided as toastmaster.

The following addresses were made:

Address of the retiring President, William G. Brenneke, "Lessons Taught by the Failure of the Quebec Bridge"; "The Need of Engineers in Municipal Government," Samuel Trepp; "Mathematics and the Engineer," Prof. C. A. Waldo; "The Engineer Citizen," A. P. Greensfelder; "The Law and the People," Arthur N. Sager.

At the conclusion of the regular addresses, Chancellor David F. Houston, of Washington University, was called on for a few remarks, and responded informally.

Adjourned.

A. S. Langsdorf, *Secretary.*

Boston Society of Civil Engineers.

Boston, November 18, 1908. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.35 o'clock p.m., President Joseph R. Worcester in the chair. Sixty-one members and visitors present.

The record of the last meeting was read and approved.

Messrs. Edwin F. Allbright, Henry M. Chadwick, John E. Cunningham, Oliver W. Hartwell, Howard B. Loxterman, Rolf R. Newman and Richard H. Rich were elected members of the Society.

Mr. Frederic H. Fay was elected a Director of the Society for the term expiring in March, 1909.

Mr. C. W. Sherman for the committee appointed to prepare a memoir of our late associate, Irving T. Farnham, presented and read the report of that committee.

The Secretary announced the deaths of two members of the Society, G. Edward Sleeper, who died October 25, 1908, and Arthur W. Hunking, who died November 12, 1908.

By vote of the Society, the President was requested to appoint committees to prepare memoirs. The President has appointed as these committees the following members: On memoir of Mr. Sleeper, Mr. Frank O. Whitney; and on memoir of Mr. Hunking, Mr. Frank S. Hart.

An invitation was read from the Secretary of the First New England Conference called by the governors of these states, inviting members of this Society to be present at the meetings to be held in Boston on November 23 and 24, at which the following topics will be considered: Tree Planting, Protection and Promotion of Supplies of Sea Food, and Highways and Their Use.

The report of the Committee on Larger Membership and Club House presented at the last meeting was then taken up for discussion, and on motion of Mr. Hodgdon, the report was accepted. On motion of Mr. Winslow it was voted to consider the recommendations of the committee *seriatim.*

It was moved and duly seconded that the following recommendation of the committee in relation to a club house be adopted: "That the Special Committee on Quarters be instructed that it is the desire of this Society that more convenient quarters be secured and that said committee take up the active consideration of this subject and report to the Society at the earliest opportunity."

Mr. Thompson moved the following amendment: "The committee is further instructed to confer with the officials of the New England Water Works Association, the Society of Gas Engineers, the Section of Institute of Electrical Engineers, the Boston Society of Architects, the Boston Architectural Club, and any other societies interested, with a view to combining the quarters of these various societies." After considerable discussion the amendment was adopted.

At this point the President called attention to the by-law requiring the literary exercises "to begin not more than a half hour after the meeting is called to order," and ruled that business must be suspended.

After the literary exercises, the discussion of the report of the Committee on Larger Membership and Club House was resumed, the question being on the adoption of the recommendation of the committee in relation to a club house as amended by the meeting.

Mr. E. H. Gowing offered the following motion as an amendment in substitution for the question before the meeting:

Voted: That the Committee on Larger Membership and Club House be continued and instructed that it is the earnest desire of the Society to acquire a permanent home or club house at the earliest feasible time; that the Society desires the committee to confer with the New England Water Works Association, the Architectural Societies, the Gas Engineers, the Railway and Railroad Clubs, and any other association which may be suggested or which, in their opinion, might be desirable to have coöperate with this Society in securing a suitable building; that the committee carefully investigate the question of financing a building or club house, and report at length as soon as possible.

A general discussion followed, and at its conclusion the amendment was adopted. A vote was then taken on the original motion as amended, and it was carried.

The consideration of the second portion of the report of the committee

in relation to larger membership was then taken up, and after considerable discussion it was finally voted, on motion of Professor Breed, that this portion of the report be considered at a special meeting of the Society to be called by the President.

The literary exercises of the meeting consisted of a very interesting and instructive paper by Mr. J. G. Callan, of the General Electric Company, entitled, "The Small Steam Turbine considered from an Engineering and Commercial View-Point." The paper was very fully illustrated by lantern slides and a 5-kw. Curtis single stage horizontal condensing steam turbine was also exhibited.

A discussion followed in which Messrs. F. W. Dean, W. H. Herschel and others took part.

After passing a vote of thanks to Mr. Callan for his valuable paper, the Society adjourned.

S. E. Tinkham, *Secretary.*

Boston, Mass., December 11, 1908. — A special meeting of the Boston Society of Civil Engineers was held at the Boston City Club, 9 Beacon Street, Boston, at 7.45 o'clock p.m., Vice-President Henry F. Bryant in the chair. Fifty-one members present.

The chairman announced that the meeting had been called by the President, in accordance with a vote of the Society passed at the last meeting, to consider the suggestions in relation to a larger membership made in the report of the Committee on Larger Membership and Club House presented at the October meeting, and to act upon the same or any modifications thereof.

The six suggestions offered in the report were then fully and freely discussed. The Secretary read a communication from Mr. George B. Francis and other members of the Society in New York City, from Mr. Laurence Bradford, from Edwin F. Dwelley and from Mr. Andrew D. Fuller, bearing on the subject under discussion. The last two communications were by vote referred to the Committee on Larger Membership and Club House.

Action was taken on the six suggestions as follows:

Suggestion 1. Establishment of a Bureau of Registration. *Voted:* That it is the sense of this meeting that a bureau of registration for members seeking employment or a change of position should be established by this Society and that the Committee on Larger Membership and Club House be instructed to formulate a plan for the establishment of such a bureau and report the same to the Society.

Suggestion 2. Additional Informal Meetings. After an explanation of what the Board of Government is doing in relation to these meetings, no action was taken.

Suggestion 3. Increased Circulation of the *Bulletin.* It was voted that the Board of Government be requested to send the *Bulletin* gratis to such of the larger engineering offices as it deems expedient.

Suggestion 4. Publication of the Proceedings and Papers of the Society in a journal of its own. After a very free discussion of this suggestion, it was voted to lay the matter on the table.

Suggestion 5. Formation of Additional Sections of the Society. The following resolution was adopted: *Resolved,* That this meeting favors the

formation of additional sections and respectfully suggests to the Board of Government the possibility of creating more active interest in the Society by the appointment of certain committees to investigate and report to it upon the feasibility of forming additional sections.

Suggestion 6. Annual Meeting to be made more of a function. *Voted:* That the Society approves the recommendation of the committee, and that the matter of arranging for the annual meeting be referred to the Board of Government with full powers.

Adjourned.

S. E. TINKHAM, *Secretary.*

BOSTON, MASS., DECEMBER 16, 1908. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.40 o'clock P.M., President Joseph R. Worcester in the chair. One hundred and ten members and visitors present.

The records of the last regular and the special meeting of December 11, 1908, were read and approved.

Mr. John G. Andrews was elected a member of the Society.

The Secretary announced the death of Charles D. Elliot, a member of the Society, which occurred December 10, 1908, and by vote the President was requested to appoint a committee to prepare a memoir. The President has appointed as that committee Messrs. G. A. Kimball, J. A. Holmes and C. A. Pearson.

The Secretary reported for the Board of Government that it had appointed Mr. H. K. Barrows a member of the Committee on Excursions in place of Mr. E. M. Blake, resigned, and Mr. E. S. Larned a member of the Committee on Larger Membership and Club House in place of Mr. C. R. Gow, resigned.

A series of papers was then presented and read under the general title, "Boylston Street Bridge, Boston, from 1888 to the present time; the destruction and reconstruction of a bridge subjected to locomotive fumes and increasing car loads."

Mr. Frederic H. Fay described the design and construction of the original bridge built in 1888; Prof. Chas. M. Spofford followed with an account of the strengthening of the bridge in 1907 for the Boston Elevated Railway Company; Mr. Fay then described the rebuilding of the bridge in 1908 for street traffic, and Mr. John C. Moses gave an account of the erection work in connection with the rebuilding of both portions.

All the papers were fully illustrated with lantern slides. A general discussion followed.

Adjourned.

S. E. TINKHAM, *Secretary.*

SANITARY SECTION.

A special meeting of the Sanitary Section of the Boston Society of Civil Engineers was held at the Boston City Club on Wednesday, December 2, at 7.30 P.M. Mr. J. Pickering Putnam read a paper entitled, "Some Anomalies in Modern Plumbing Regulations." This paper was illustrated with lantern slides. Mr. David Craig, President of the Master

Plumbers' Association; Mr. James C. Coffey, Executive Officer of the Worcester Board of Health; Mr. Charles R. Felton, City Engineer of Brockton, and others took part in the discussion.

Thirty-three members and guests were present.

The next meeting will be held in February.

ROBERT SPURR WESTON, *Clerk*.

Montana Society of Engineers.

BUTTE, MONT., NOVEMBER 14, 1908. — The regular meeting of the Society for the current month was called to order at the usual time and place, Vice-President C. H. Bowman presiding. The minutes of the October meeting were submitted and approved. Charles Henry Schmalz was elected to active membership in the Society. The following resolutions on the death of Messrs. Abbott and Beckler were read and endorsed.

Resolutions on the death of A. A. Abbott:

Whereas, In the death of A. A. Abbott the Montana Society of Engineers has suffered a great loss, and desiring to place on record its appreciation of his high character, both as an engineer and as a man, and of his conscientious discharge of every duty intrusted to him; therefore, be it

Resolved, That this Society shall express, by these resolutions, its sincere sorrow on the death of Mr. Abbott, and these resolutions shall be spread upon the minutes of the Society and a copy forwarded to his bereaved family.

J. C. ADAMS,
B. H. DUNSHEE,
C. H. MOORE,
Committee.

Resolutions on the death of Mr. E. H. Beckler:

Whereas, Death has claimed Mr. E. H. Beckler, a charter member of the Montana Society of Engineers, and a former president of the Society,

Be it resolved, That the Montana Society of Engineers does hereby condole with the whole engineering profession in the loss of a thorough engineer and a true man, and that in order to respect the memory of Mr. Beckler this resolution be spread upon the minutes of the Society and a copy be furnished to surviving members of his family.

JOHN GILLIE,
EUGENE CARROLL,
FRANK L. SIZER,
Committee.

BUTTE, MONT., November 11, 1908.

On motion, it was decided to hold the next annual meeting at Great Falls, Mont., January 7–8–9, 1909, and President Wheeler was requested to name a Committee of Arrangements to prepare a program for that event. The Secretary was instructed to prepare obituary notices respecting Messrs. Abbott, Baker and Beckler for publication in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES. Mr. J. H. Harper gave his views on the duties of the State Engineer with particular reference to the supervision and approval of the construction of power dams in Montana by said official. The Committee on Nomination of Officers for the ensuing year not being able to report, the meeting was adjourned to Saturday evening, November 21.

CLINTON H. MOORE, *Secretary*.

ADJOURNED MEETING.

BUTTE, MONTANA, NOVEMBER 21, 1908. The meeting was called to order by Vice-President Bowman. Quorum present.

The following resolutions on the death of John S. Baker were presented and approved.

Resolutions upon the death of Mr. John S. Baker:

Whereas, The Montana Society of Engineers is again called upon to mourn the loss of one of its most earnest members, Mr. John S. Baker, an engineer of marked ability in his chosen branch of the profession, and a man of sterling integrity and high character in all his dealings with his fellowman; and

Whereas, While he was physically afflicted in such a way as to render the outdoor life of the engineer probably very burdensome and wearying at times, yet he never complained, but always held up his end in a way that should stand as an example to the young men of the profession who have hard tasks thrust upon them but have no physical impediments to in any way hinder their accomplishment; and

Whereas, It is most fitting that this Society should take notice of its loss and should make some record of it; therefore, be it

Resolved, That in the death of Mr. John S. Baker, the Montana Society of Engineers has lost one of its most talented members, and the state of Montana, an engineer of marked ability, who, had he lived, would have rendered our grand state much valuable service in the development of its natural resources now lying dormant, awaiting but the help of capital and the skill of the engineers to bring them into activity and usefulness. Be it further

Resolved, That this Society expresses its sorrow to the relatives of our departed brother, and that a copy of these resolutions be sent to them and another copy be spread on the minutes of the Society.

Respectfully submitted,

ROBERT H. LINDSAY, JR.,
JOHN D. POPE,
ROBERT A. MCARTHUR,
Committee.

The Committee on Nomination of Officers for the Society for 1909 presented the following list and it was approved:

President — Charles H. Bowman.
First Vice-President — Frank M. Smith.
Second Vice-President — F. W. C. Whyte.
Secretary and Librarian — Clinton H. Moore.
Treasurer and Manager of Board — Samuel Barker, Jr.
Trustee — Theo. Simons.

Respectfully,

EUGENE CARROLL,
GEO. E. MOULTHROP,
W. T. BURNS,
Committee.

The Secretary was instructed to circulate the ballots for the same. Messrs. Goodale and Moore were appointed a Committee on Transportation.

Adjournment.

CLINTON H. MOORE, *Secretary.*

BUTTE, MONTANA, DECEMBER 12, 1908. — The usual meeting for the month was called to order on the above date at 8 P.M. Vice-President Chas. H. Bowman presided. After the reading and approval of the min-

utes of the November meetings, the Secretary presented the applications of the following candidates for membership in the Society: James A. Bow, Arthur Crowfoot, Archibald T. Elliott, David M. Folsom, Charles O. Jenks, George Kuehner, Charles E. Livers, Leon M. McAllister, Charles E. Rowe and Peter Thill. These applications being approved, the Secretary was instructed to prepare the usual ballots. Messrs. Frank D. Jones and Frank Scotten were reinstated. Obituary notices on the death of A. A. Abbott and John S. Baker were read by the Secretary and were recommended for publication in the Journal of the Association of Engineering Societies. Further time was granted for a like notice on the death of E. H. Beckler. The Committee on Transportation made a brief report, not definite, on account of lack of final reply from Great Northern Railway officials. After a very interesting account by Vice-President Bowman of his observations at the late Mining Congress, held at Pittsburg, Penn., adjournment followed.

Clinton H. Moore, *Secretary.*

Utah Society of Engineers.

Salt Lake City. — Society met in main dining room of Commercial Club, Salt Lake City, Friday evening, December 18, and the evening was celebrated as an " Engineering Smoker," there being about forty members present.

Dr. W. C. Ebaugh, Ph.D., of the State University, delivered a highly instructive and interesting address on " Smelter Smoke Treatment," minutely describing the construction and operation of the various methods of " treatment " employed or tested by the smelters of the Inter-Mountain region.

Mr. Richard S. McCaffery, until recently metallurgical director of the Tintic Smelter, read an original paper dealing with "Blast Furnace Operation," especially with regard to the constitution and formation of slag.

Both papers were thoroughly discussed by the members present and a unanimous vote of thanks was tendered the two members presenting papers.

The next meeting will be held in the Physics Building, State University, January 15, when a paper will be presented by Mr. Leonard Wilson, resident manager for the General Electric Company, dealing with "Transformer Substations," and Prof. E. H. Beckstrand will deliver an address on "Testing of Materials."

D. McNicol, *Secretary.*